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COMPUTER ANALYSIS OF LONGITUDINAL STRENGTH OF SHIPS.

by

R. A. SELBY, B.Sc.

Thesis submitted to the  
University of Durham, August 1967,  
for the award of M.Sc.



ABSTRACT OF THESIS ON  
COMPUTER ANALYSIS OF LONGITUDINAL STRENGTH OF SHIPS

The purpose of the work was to produce a programme to calculate as accurately as possible the distributions of weight and buoyancy of a vessel, leading to the determination of shear force and bending moment at each of 101 equally spaced ordinates overall.

Calculations may be performed for still water or sine wave conditions.

The programme, which provides tabular and/or graphical output, is written in Elliott Autocode and is in the Applications Group library of Elliott Automation Limited. It is extensively labelled and is flow charted throughout, the symbols used being those of the British Standards Institution, and illustrated in the glossary.

A fairly detailed look into the 'end lengths' suggested by Lloyd's (their Rpt. SR 64/15) has been undertaken in connection with the distribution of the continuous material.

Ordinate tilting has been used, in the main, as opposed to 'base swinging' techniques, the reasons being fully explained in the text.

The programme was approved by Lloyd's Register of Shipping in August 1966, (except for those parts relating to (i) the coffin method for the continuous material and (ii) the application in a sine wave -

which parts Lloyd's did not check). It has also been further successfully tested by them in November, 1966.

Comparisons with programmes written by Vickers Armstrongs Limited, Barrow in Furness, B.S.R.A., Wallsend, and the Naval Architecture Department of Glasgow University, on the same topic are included as an Appendix. Graphical results obtained by Lloyd's, B.S.R.A's and by this programme for one locally built vessel are included, for purposes of comparison.

Results illustrated in the thesis are in both tabular and graphical form throughout.



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## INTRODUCTION

The structure of a ship is subjected to a variety of forces, which may be split into two main types : statical and dynamical. One of the effects of such forces is to cause the vessel to bend in a longitudinal vertical plane. The following thesis deals with this aspect only; i.e. it is an analysis of the longitudinal strength of vessels.

The vessel may be treated as a beam, subjected to forces which consist of:

- |       |                                     |   |               |
|-------|-------------------------------------|---|---------------|
| (i)   | its own weight                      | } | Total Weight. |
| (ii)  | cargo, fuel, machinery, etc.        |   |               |
| (iii) | buoyancy - (to equal Total Weight). |   |               |

Bending occurs because weight and buoyancy are not, in general, equal at all points along the length of the vessel. There may be an excess of weight over buoyancy at some points (especially the ends), and an excess of buoyancy over weight at other points along the length.

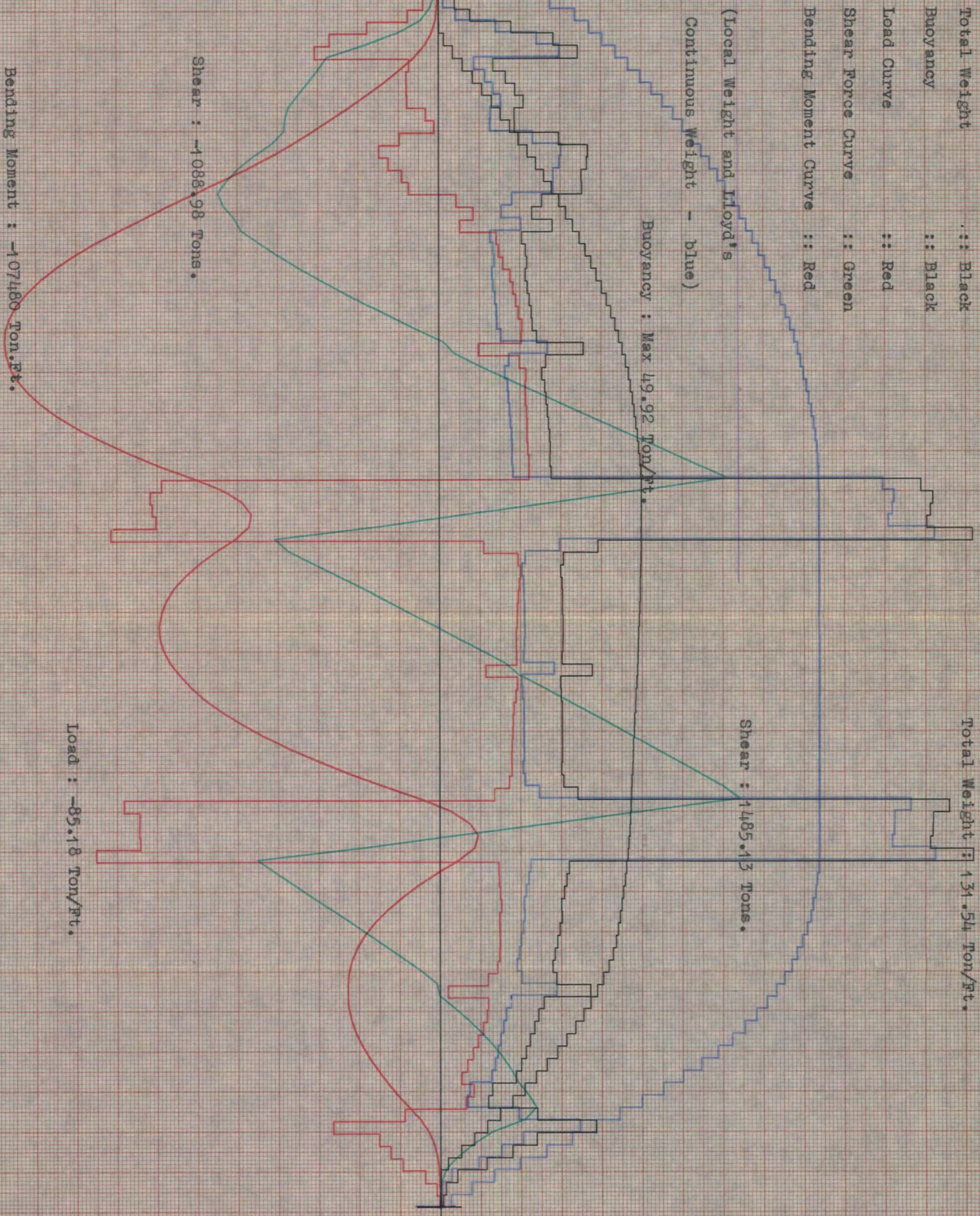
The calculations are carried out by determining the weight and buoyancy distributions (curves) along the ship's length, and from these two the determination of LOAD curve which is the difference (with sign) between these curves.

Integration of the load curve gives the SHEAR FORCE curve, and a second integration gives the BENDING MOMENT curve.

Page (ii) shows the various curves for the ship considered in the thesis with vertical scales half of those of the separate graphs in the body of the thesis.







Total Weight : 131.54 Ton/Ft.

Total Weight :: Black  
Buoyancy :: Black

Load Curve :: Red

Shear Force Curve :: Green

Bending Moment Curve :: Red

(Local Weight and Lloyd's

Continuous Weight - blue)

Buoyancy : Max 49.92 Ton/Ft.

Shear : 1485.13 Tons.

Shear : -1088.98 Tons.

Load : -85.18 Ton/Ft.

Bending Moment : -107480 Ton.Ft.



The programme calculates and prints out, if desired, ordinate values for Local Weights, Continuous Hull Weight, Total Weight, Buoyancy, Load Curve, Shear Force Curve and Bending Moment Curve over each of 100 equal divisions of the ship's overall length.

Weight, buoyancy and load curve ordinate values are averaged over every pair, progressively, throughout the whole length; ordinate values output are, therefore, projected forward over the appropriate division, in the first five tables mentioned above.

There are checks in the programme to ensure that extreme ends of local weights lie within the overall length of the vessel and also that the centre of gravity of each local weight lies within the centre  $33\frac{1}{3}\%$  of the length of the item. The programme waits if any item offends and may be continued if desired.

The graphs of the Weight, Buoyancy and Load Curves consist of a series of straight horizontal lines drawn forward from each ordinate in turn (in agreement with the tables mentioned above). In the case of the Shear Force and Bending Moment, however, continuous polygons are drawn.

If it is necessary to produce Shear Force graphs for several conditions, to a common scale (and similarly for Bending Moment curves), then an initial run of the conditions must be made to obtain the maximum positive and maximum negative values overall. Re-running the data with these values inserted will enable a common scale to be set for all conditions. See appendix 4, Page 183.

Since a large amount of output tape is required to draw axes and insert scales, it is left to the design office to insert the axes manually, and to write the scales in. (The size of scale is automatically output if the graphs are required).

The time taken to output all of the above listed tables is approximately 8 - 10 minutes. Output for the graph-plotter only, takes approximately two minutes per graph. Full output of all tables and graphs takes, therefore, approximately 22 minutes.

(A preliminary programme was first written, using as a basis a ship from a local yard for which results had already been calculated - using Biles' Coffin continuous weight distribution - and for which graphs had been plotted, by hand. This ship is referred to as Ship No. A827. The effects of buoyancy due to the stern and bow sections were ignored in this programme; the length between the perpendiculars was divided into ten equal parts, numbers 1, 2, 9 and 10 being further halved giving, in all, 15 stations. The programme uses the Biles' Coffin method to distribute the continuous weight.

Results output by this shorter programme have been superimposed on the graphs provided by the yard, for the still water calculations. See Appendix 2).

The main programme includes the stern and bow portions. Thirty one stations are used over all, of which 23 are within and include the perpendiculars, with 4 aft and 4 forward.

Since the work started Lloyd's have published their method for the distribution of the continuous weight entitled:-

CARGO SHIPS  
DISTRIBUTION OF LIGHTWEIGHT  
FOR STILL WATER BENDING  
MOMENT CALCULATIONS  
RPT. SR 64/15.

This method is included in the main programme, and the choice of distribution is left to the builder.

(It may be pointed out that for the present the report may be taken as applying to bulk carriers and tankers, though it is expected that a separate work will be published concerning these types of vessels).

Some interesting points arose in the choice of the stern and bow overhangs (and their respective weights) when considering the continuous weight distribution by both Lloyd's and Biles Coffin methods. Since the programme is to cater for the builder in the design stages, when such values are not known with certainty, Lloyd's suggest possible end values for their method. These were investigated, and the results may be examined on pages 57/61. Page 34 deals with the Biles Coffin aspect.

Checks are made in the resultant total weight curve for correct weight and L.C.G. position, and if any final error is present, it is ultimately corrected by the axis swinging technique known as 'swinging the base'. It is expected that such errors will be negligible, if Lloyd's method is used for the continuous weight. Checks included print out the errors and hold up the programme if the weight error is greater than  $\pm .1\%$  or if the L.C.G. error is greater than  $\pm 1\%$ , before 'swinging the base'.

Data from a second ship has been used to illustrate this main programme. This ship is referred to as Ship No. A.842.

Comparisons of outputs, in tabular and graphical forms, of the Continuous Weight distributions for A842, and consequent Total Weight, Load, Shear and Bending Moment curves, using Biles Coffin method and Lloyd's method are included.

Graphs of results using the former are shown in red, and those using Lloyd's method are in green.

Since finishing this work, the author has seen and examined three other programmes of a similar nature. One is from the Naval Architecture Department of the University of Glasgow and is entitled:-

RESEARCH REPORT NO. 10

A NOTE ON STILL WATER BENDING MOMENT CALCULATIONS

BY A DIGITAL COMPUTER.

BY C. KUO AND N.S. MILLER.



The report is not for publication.

The second programme is from Vickers Armstrong (Shipbuilders) Limited, Barrow-in-Furness, entitled:-

DETAILS OF  
LONGITUDINAL STRENGTH PROGRAMME NA/4  
WRITTEN IN MERCURY AUTOCODE.

The third is a report from B.S.R.A., Wallsend-on-Tyne, describing a Longitudinal Strength programme BSRA/NA/W5. Their programme is a modified version of the Vickers programme, made to satisfy Lloyd's Register requirements.

Comparisons of these three programmes with the Sunderland programme are set out in Appendix I of this thesis.

An outline flow chart for the whole of the programme follows on page xv. Separate flow charts, one for each part of the programme, will be found preceding the first pages of their respective chapters, with those for Subroutines 30 and 86 preceding the print-up of the programme, in Appendix 3.

Subroutines 29 (moments), 58 (Lagrange's 3 point interpolation) and 109, 110 (graph output), are elementary and have not been flow charted.

Presentation of data, and methods of operating the programme are set out in Appendix 4, and is a copy of the write-up now sent to Elliott's Application Group for general distribution.

Thanks are due to Mr. N. Tate, Senior Lecturer in Naval Architecture, Sunderland Technical College, for many valuable comments and help generally. Also to Mr. T. Case, until recently on the design staff of Messrs. Austin and Pickersgill Limited, Shipbuilders, Sunderland, and at present in the Research Department, Lloyd's Register of Shipping, for much valuable help and encouragement. I must also thank the design staffs of the several yards on the River Wear for their unstinted help in providing data as required. They have been extremely accommodating and encouraging. The cooperation of B.S.R.A., Wallsend, in providing results for comparison is greatly appreciated.

Finally my thanks to Lloyd's Register of Shipping for checking the results of this programme with their own programme for Longitudinal Strength. Lloyd's have accepted the programme for use in the initial design stages. Check computations must be performed by Lloyd's where Bending Moment results are required for plan approval, but where figures are supplied from this approved programme, no fee will be charged by Lloyd's.

GLOSSARY

(AND KEY TO FLOW CHARTS)

- "a" - multipliers which enable the ordinates of the continuous weight curve to be obtained at each of 21 positions along the length of the vessel. These values are dependent upon the block coefficient at the appropriate load draught and they are given in graphical form in Lloyd's "Rpt. SR 64/15", Figures 3 and 4.  
Copies of these figures are on pages 42/43.
- base plane - horizontal plane through the origin.
- block coefficient  
( $C_B$ ) - ratio of submerged volume at a given draught  $\underline{d}$ , to the volume of the enclosing rectangular prism having dimensions length (LBP), breadth (2xGI) and draught (d).
- Bonjean curve - curve of immersed areas for a given section, or station.
- bow  
(and overhang of) - that portion of the vessel forward of the forward perpendicular. The horizontal distance between the forward perpendicular and the extreme forward point of the vessel is referred to as the "overhang of bow".
- buttock heights - heights from the horizontal base plane to the moulded shell line.
- centre of buoyancy - point through which the resultant of the buoyancy forces acts.
- centre of flotation - centroid of the area of any given waterplane; when a vessel, floating at a waterline, is trimmed by a re-distribution of weights on board, the final and original waterplanes intersect in a line which passes through the centre of flotation.

centre of length (C/L)	- centre point in the length of a local weight item.
continuous weight	- weight of the ship structure when all concentrated items of structure and equipment are removed.
deadweight	- total weight of all concentrated items (local items) additional to lightweight.
displacement	- tonnage of sea water displaced for a given loading condition.
draught	- vertical distance between the water surface and the moulded base line.
floating point	- refers to a method of storage of numbers within the computer.
half breadth	- horizontal distance from the longitudinal centre line plane to the moulded shell line.
hogging	- a condition of the vessel wherein the buoyancy is more than the weight over approximately the midship half length with less buoyancy than weight at both ends, so that the tendency of the vessel is to arch up or hog amidships.
integer	- refers to a method of storage of numbers within the computer.
L.B.P. (or LBP)	- horizontal length between the perpendiculars.
L.O.A. (or LOA)	- extreme overall length of the vessel.

lightweight (lightship)	- continuous weight plus such concentrated items as engines, deckhouses, etc. (i.e. weight of unloaded vessel).
local weight	- weight of any item of structure, equipment or deadweight which is distributed over only a part of the length of the ship.
L.C.B. (LCB)	- longitudinal centre of buoyancy (measured longitudinally from the origin).
L.C.F. (or LCF)	- longitudinal centre of flotation (measured longitudinally from the origin).
L.C.G. (or LCG)	- longitudinal centre of gravity (measured longitudinally from the origin).
"m" value	- weight per foot of the ship structure over the midship section. (Refer to Lloyd's Rpt. SR 64/15)
midships	- centre of the distance between the perpendiculars.
moulded lines	- lines to which the ship is designed; the shell plating falls outside these lines. (See diagram - General Hull Terms : p.xiii)
origin	- vertical projection of the extreme aft point of stern onto the base line.
perpendicular (aft)	- vertical line through the after side of the rudder post, or if no rudder post is fitted, through the centre-line of the rudder stock.
perpendicular (fore)	- vertical line through the point where the stem of the vessel cuts the still waterline at the design draught.

- rudder stock - vertical axis about which the rudder turns.
- sagging - the condition opposite to hogging wherein the excess of weight over buoyancy amidships with a corresponding excess of buoyancy over-weight at the ends causes a tendency to arch down or sag at mid-length.
- still water - surface of water is a horizontal plane.
- swinging the base - adding (or subtracting) a trapezoid of area to the base of the curve to adjust the area and centroid, thereby producing a new (tilted) base. Such areas represent weight.
- trim - difference in draughts between the extreme ends of the vessel.
- waterlines - intersections between the hull and horizontal planes (waterplanes) at draughts d.

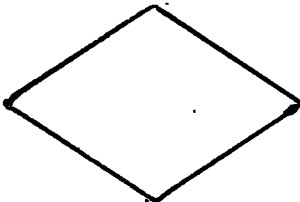
#### Flow Chart Symbols



Any kind of processing function.



Input/Output.

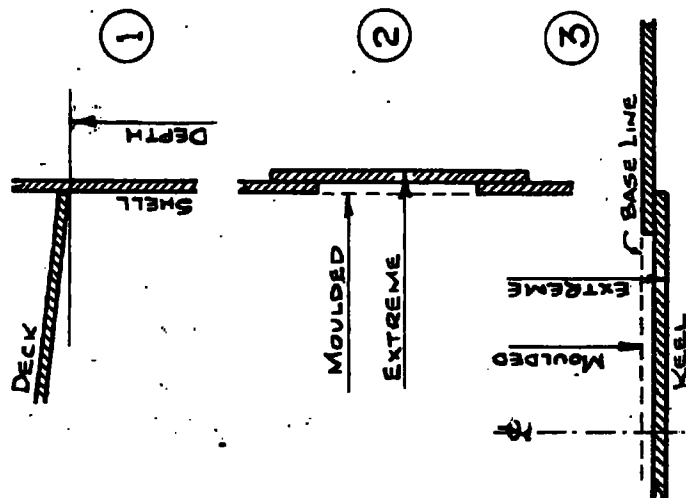
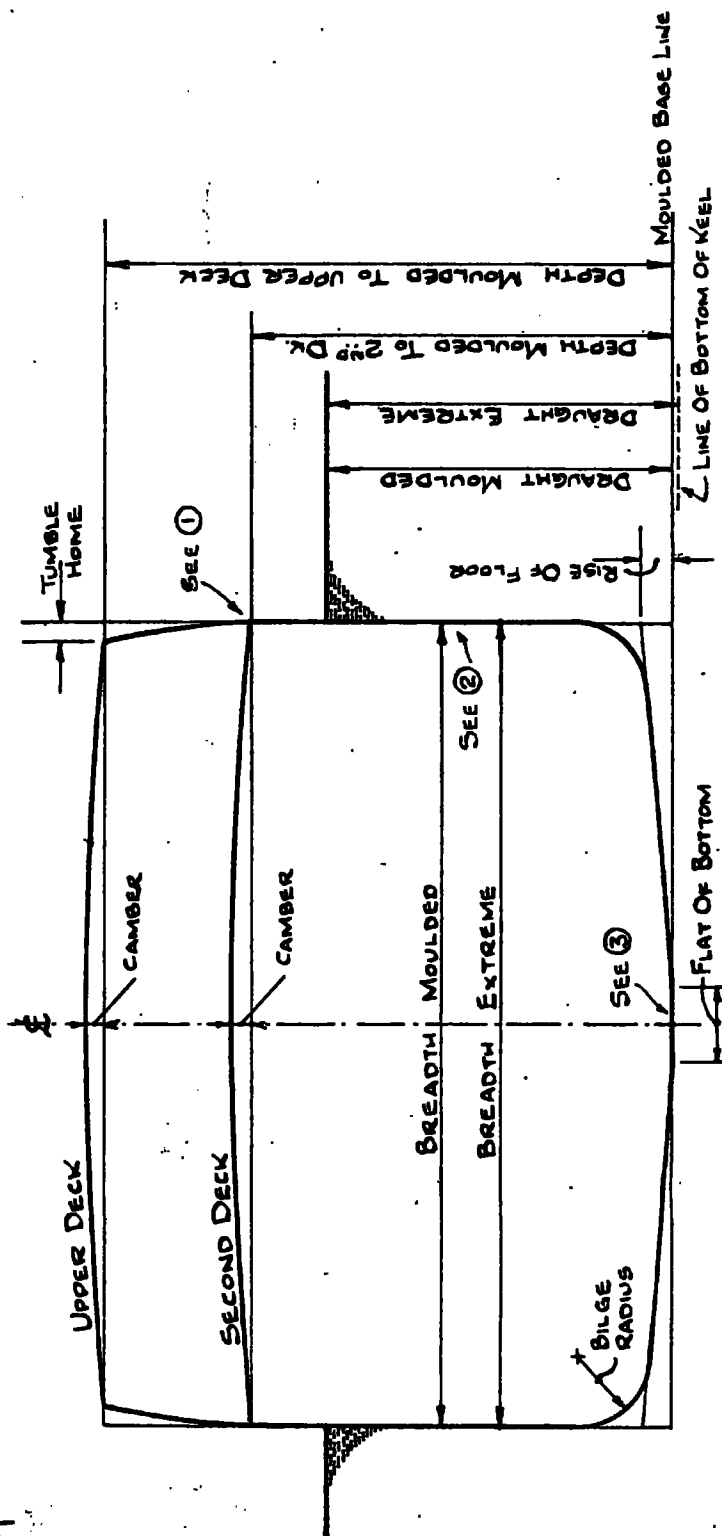
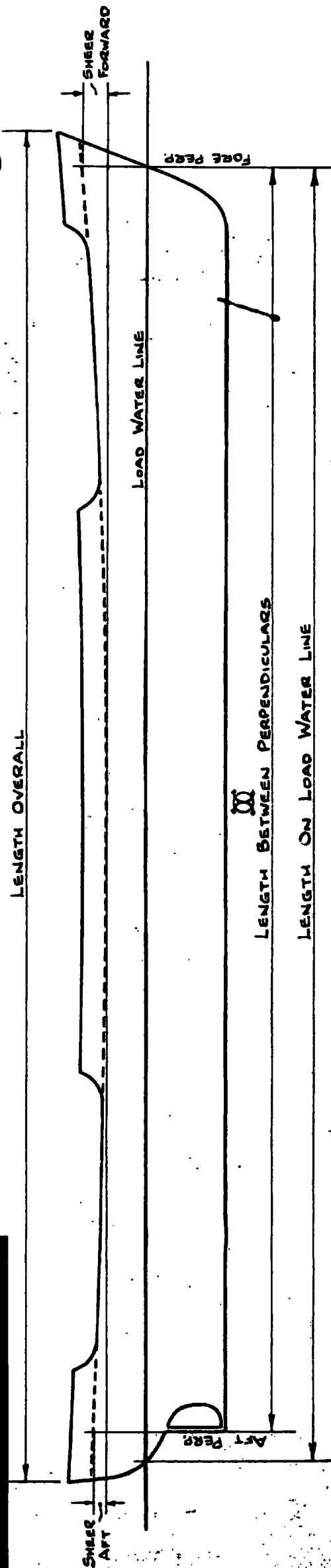


Decision or switching type operation.



Connector. An exit to or entry from another part of the flowchart.

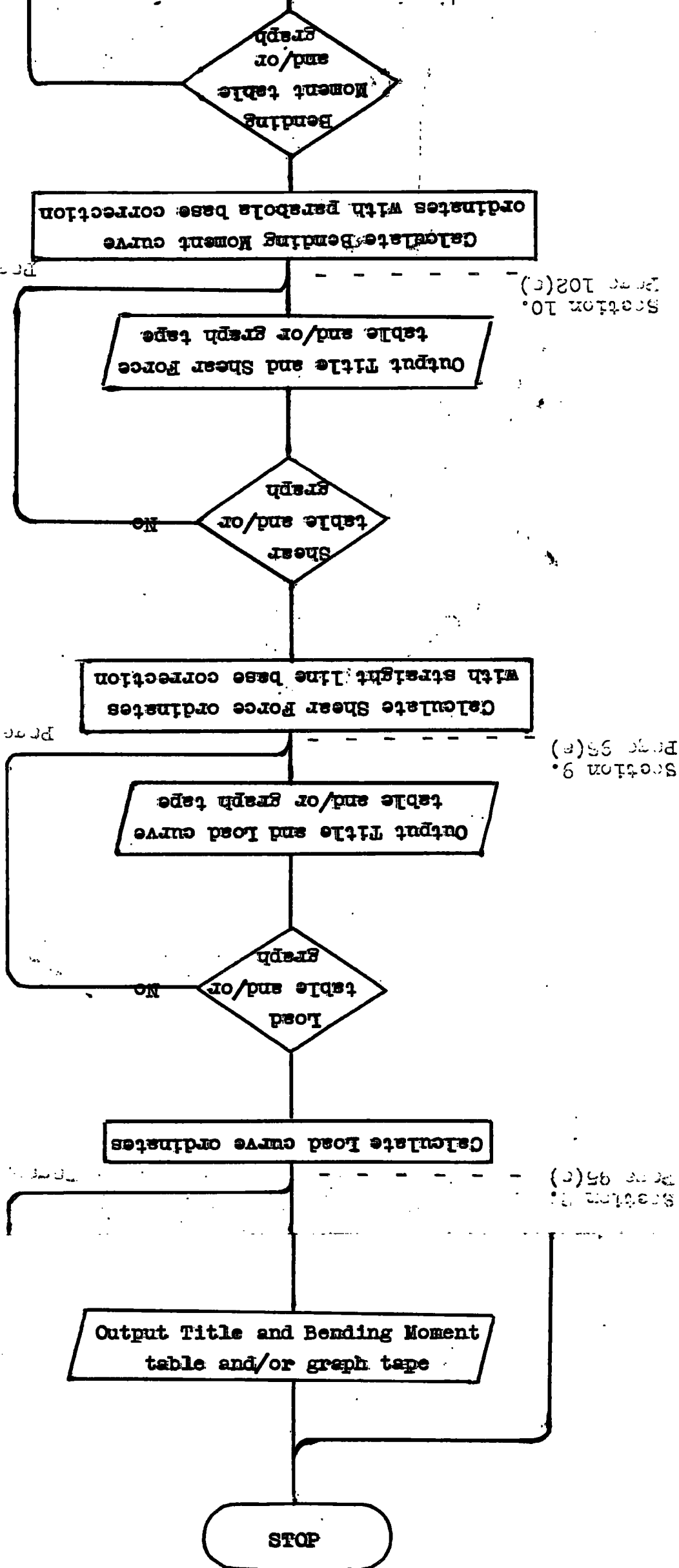
# GENERAL HULL TERMS ①



LIST OF SUBROUTINES

- 29                   -   Summation of Moments of Weight, or Buoyancy,  
                      ordinates about the extreme end of stern.
- 30                   -   Calculates the area submerged up to the water surface  
                      for the section being considered.
- 58                   -   Lagranges 3-point interpolation routine, to produce  
                      100 equally spaced values. Finds values within the  
                      first interval over the first half of the range, and  
                      changes to the second interval for the remainder of  
                      the range.
- 86                   -   Calculates and prints out:-  
                      (i)   maximum positive and maximum negative values of  
                          ordinates  
                      (ii)  range for Y-axis  
                      (iii) X-axis distance from base of graph paper  
                      (iv)  vertical scale.  
                      It also prints out the horizontal scale from the  
                      value previously read in.
- 109                  -   Produces a tape for the Benson-Lehner graph plotter  
                      for those 'curves' which are continuous polygons.
- 110                  -   Produces a tape for the Benson-Lehner graph plotter  
                      for those 'curves' which show the ordinate values  
                      projected forward.
- 124  
(inc. 34,  
      35,  
      36,  
      46,  
      64.  
                      -   Distributes the local weights over 100 equally spaced  
                      ordinates between the extreme ends of the vessel.  
                      Prints out error indications where the item lies out-  
                      side the overall length (Q2 if to rear of stern, Q3  
                      if forward of point of bow), and where L.C.G's of  
                      items are greater than one sixth the length of the  
                      item (indicated by the letter B), in both cases also  
                      giving the number of the item.





1. *Chlorophyll *a** and *Chlorophyll *b** were determined by the method of Arar and Collins (1971) using a Shimadzu 1601 UV-Visible Spectrophotometer.

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*Journal of Management Education* 30(6)

For the purpose of this study, the following hypotheses were formulated:

100

[illegible]

1. *Chlorophyll a* and *Chlorophyll b* were determined by the method of Arar and Collins (1971) using a Shimadzu 1010 spectrophotometer. The concentration of chlorophyll was expressed as  $\mu\text{g mL}^{-1}$  of the sample.

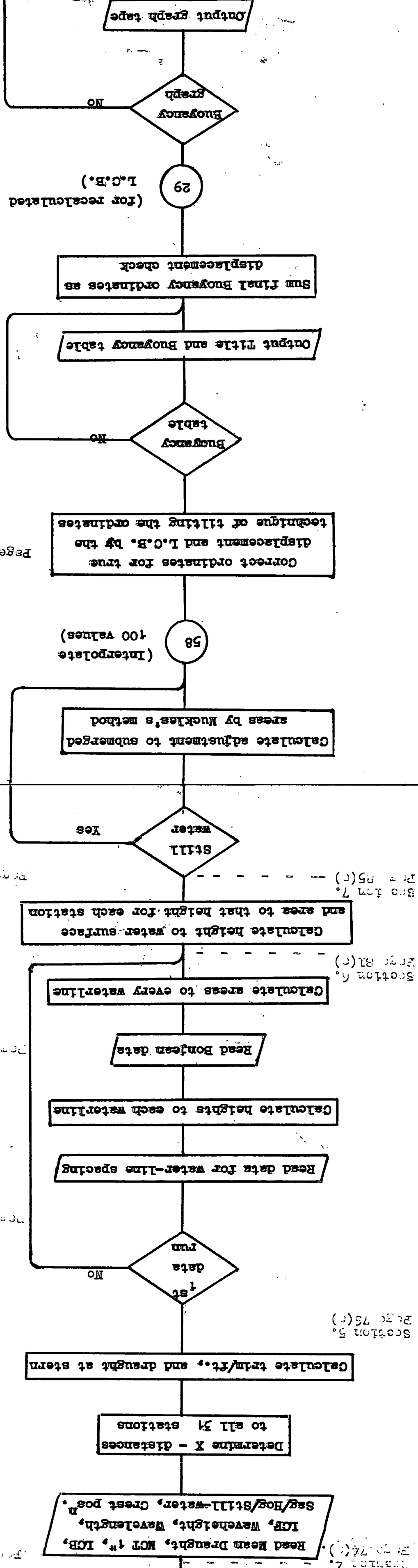
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E	O	L	D

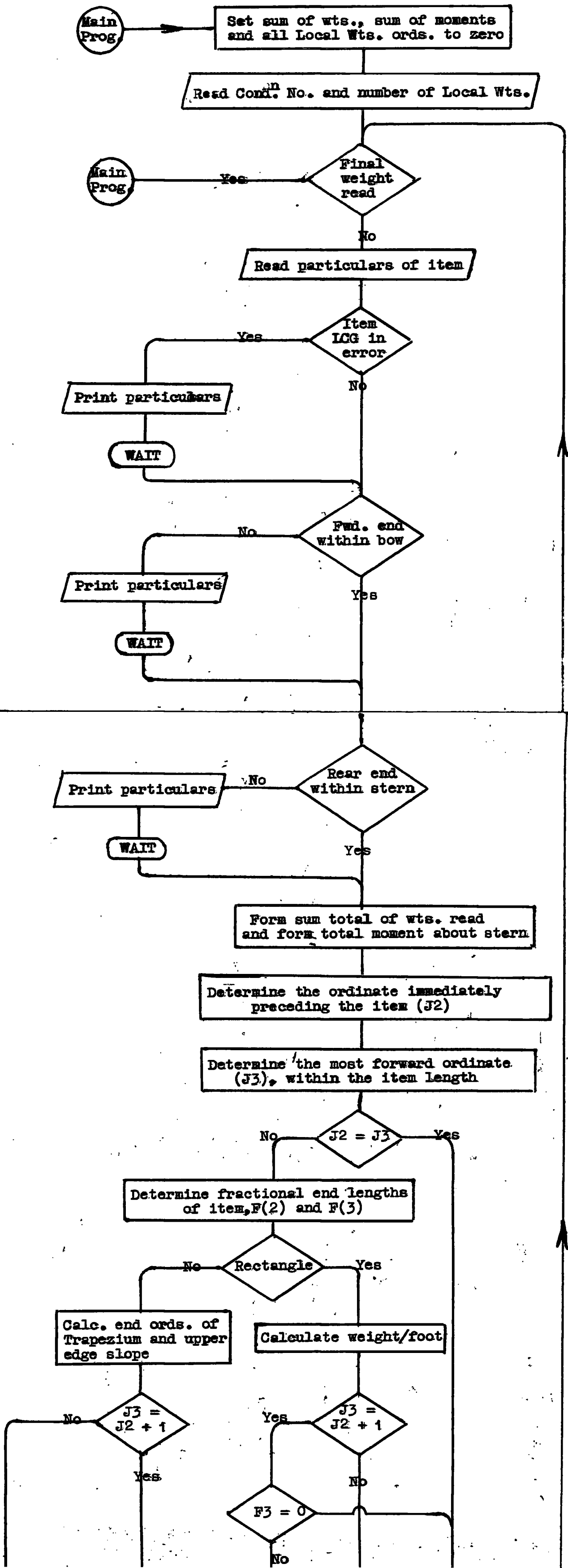
OVERALL FLOW-CHART.

## BENDING MOMENT CALCULATIONS

**LONGITUDINAL STRENGTH**



## LOCAL WEIGHTS SECTION (Subroutine 124)

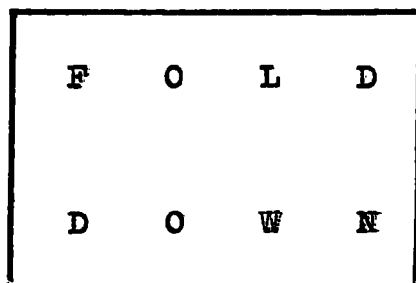


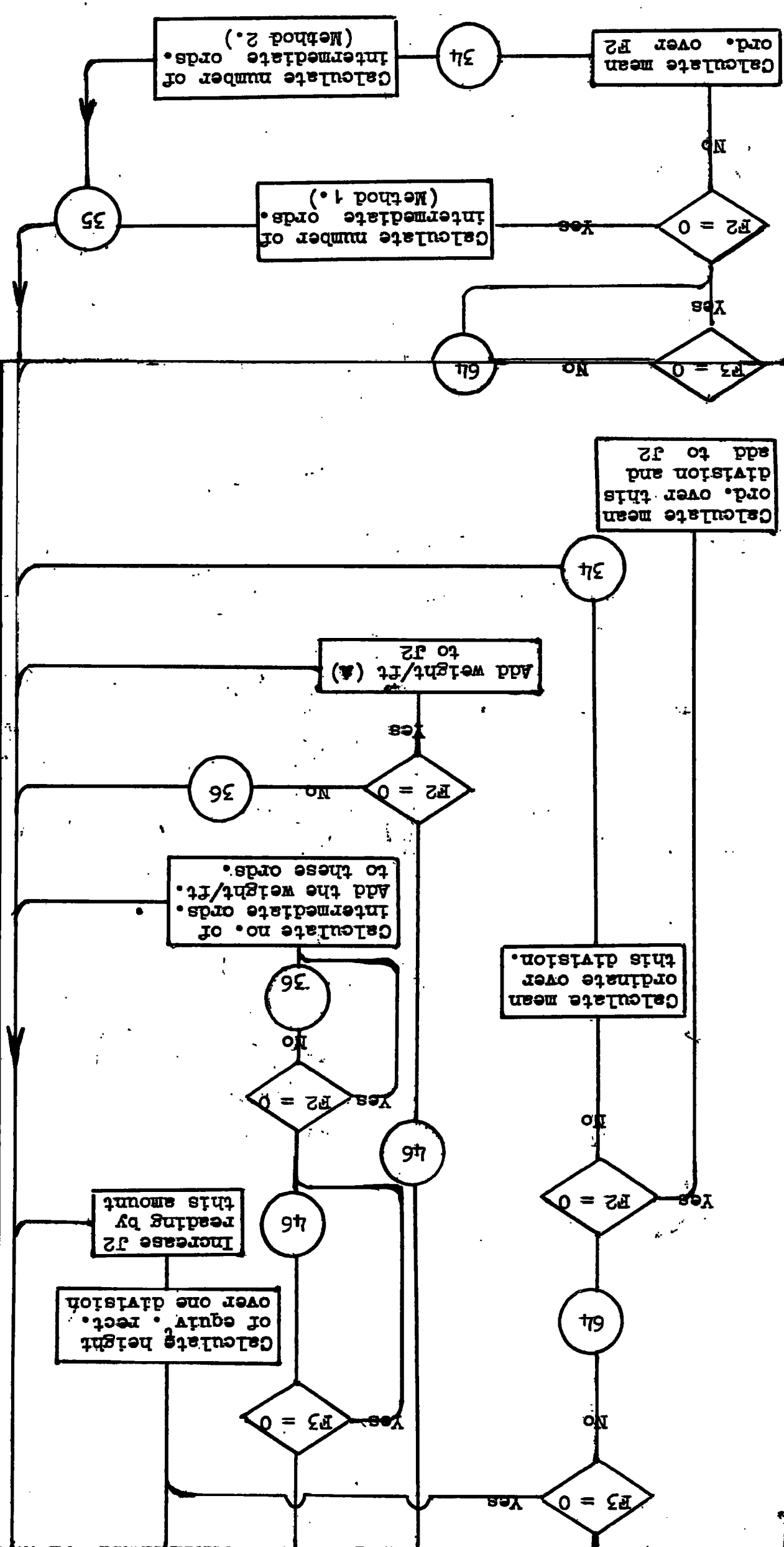
FLOW CHART

(Section 1).

LOCAL WEIGHTS SECTION

(Subroutine 124)

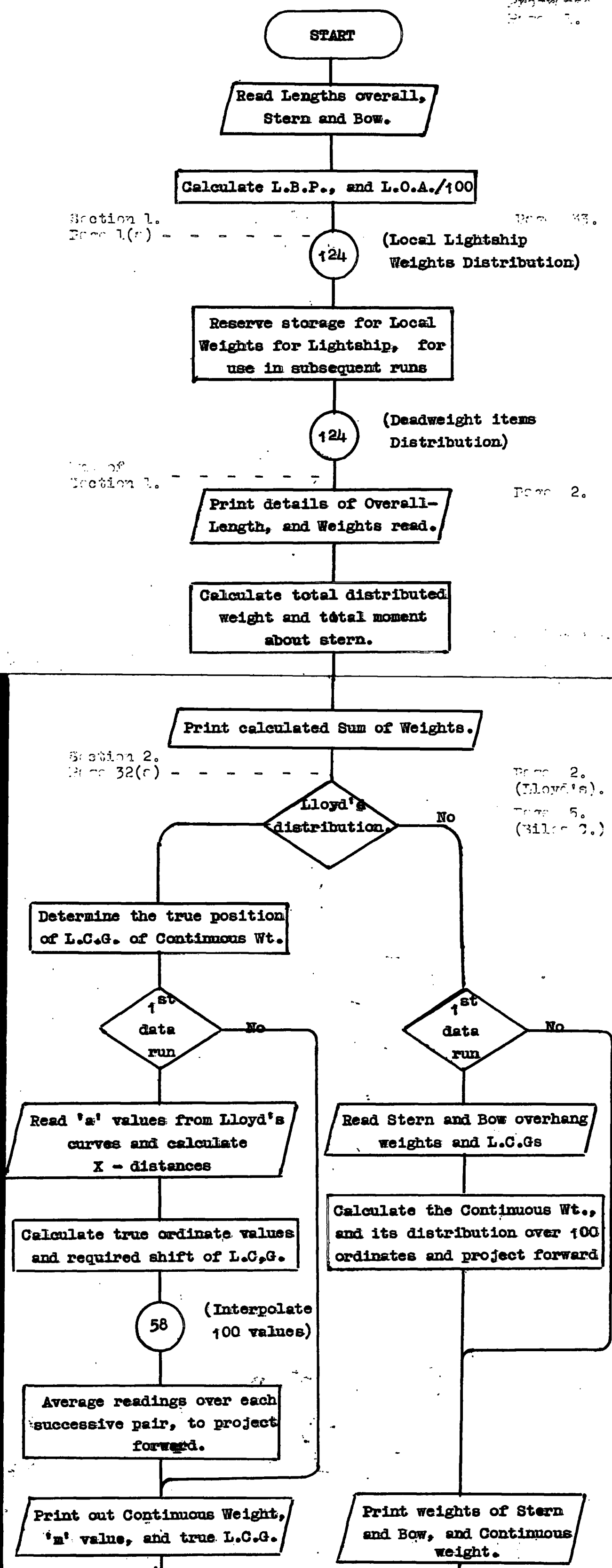


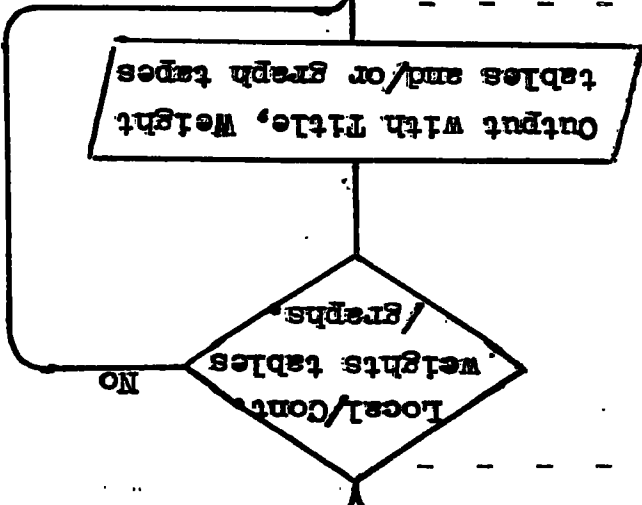


LONGITUDINAL STRENGTH

BENDING MOMENT CALCULATIONS

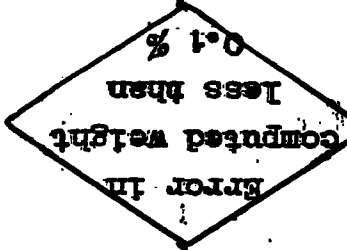
OVERALL FLOW-CHART





(For provisional L.C.G.)

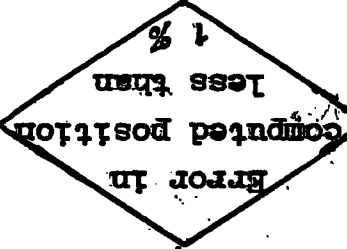
29



Print error

WAIT

Carry on if desired, else remove programme.

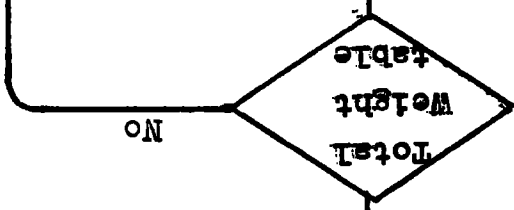


Print error

WAIT

Carry on if desired, else remove programme.

Enter 'Base swinging' calc. to correct for errors in weight and L.C.G.

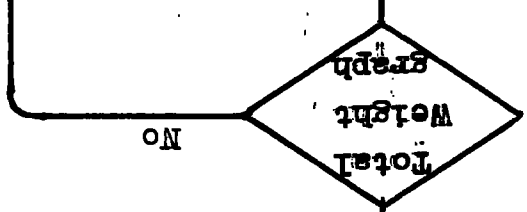


Print Title and Weight table

(For recalculated L.C.G.)

29

Print out Total Weight and L.C.G.



Output graph tape



PART 1  
LOCAL WEIGHTS DISTRIBUTION

Local Weights are all the additions to the basic hull and include such items as cargo, masts, ballast, deckhouses, winches, wheelhouse, hatch-covers, engines, etc.

For the distribution of local weights the overall length of the ship (L.O.A) is divided into 100 equal parts, and the division marks, or ordinates numbered from 0 (the stern) to 100 (the bow). Each weight item is then distributed over those divisions in which it lies, as a series of weight ordinates. The distribution of the actual weight in any particular case may be uniform over its length, or it may vary over its length either linearly or befitting some curve. The latter method was considered and rejected, it being decided that such distributions may be split into smaller portions which may be assumed to vary linearly. The actual weight distribution in a particular case, therefore, may be rectangular or trapezoidal. Each type is dealt with in the programme.

A series of test weights were used initially, and the details relating to them are set out on pages 13 to 22.

The weights relating to the actual ship under test (Ship A.842), were then used in the programme and these items are set out on pages 24 to 28. The ordinate values as output from the programme are on page 30 and the appropriate graph on page 31.

Note that ordinate values are averaged over every pair progressively throughout the whole length, the value being attributed to the rearmost ordinate; ordinate values output are, therefore, projected forward over the appropriate division.

Output of the table of values is optional, on the desire of the builder.

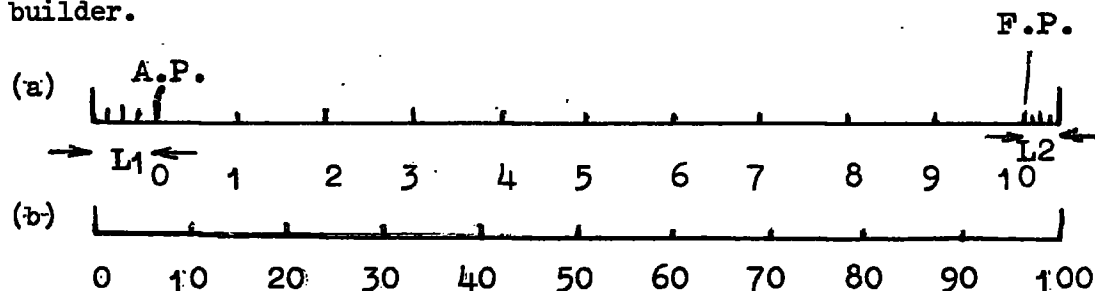


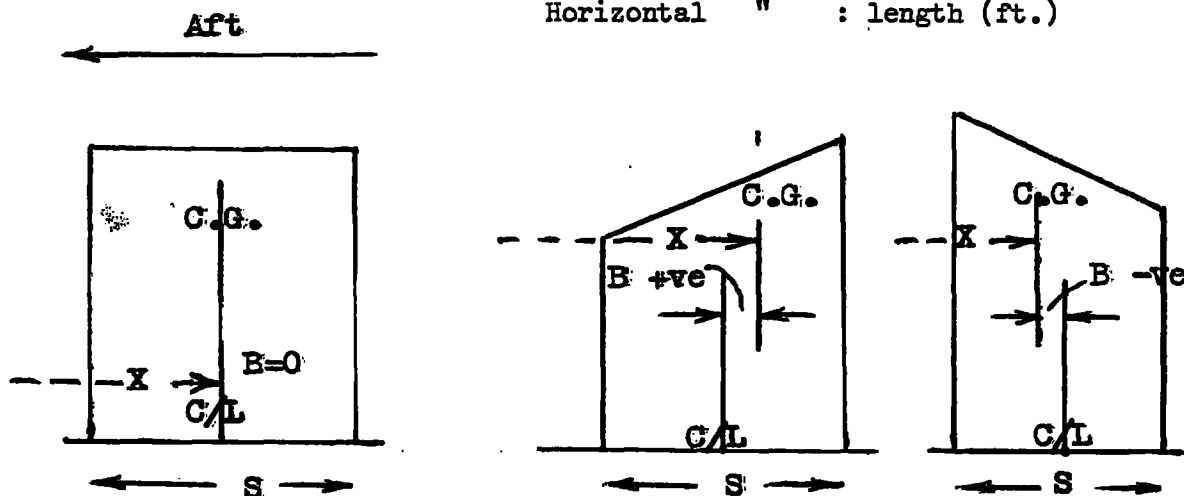
Fig. 1. Showing how the L.O.A. is divided into 100 equal parts (b), and the relationship to the normal 10 displacement stations (a).  
L1 - overhang of stern. L2 - overhang of bow.

The relevant information for each weight is read in and consists of (a) the weight, (b) its length, (c) the distance of its centre of gravity from its centre of length (C/L) and (d) the distance of its centre of gravity from the Z axis through the extreme point of stern. F. Pt. variables are M, S, B and X respectively. B may be zero, positive or negative according as the weight plan is rectangular or otherwise. See fig. 2. (In this thesis W is used for local weights instead of M).

The calculations are performed within a VARY loop which covers the number of local weights to be dealt with (Int. variable N). Local weights read in are summed immediately (F. Pt. variable S1), as are their moments about the Z axis through the extreme point of stern. (F. Pt. variables M1 - individual, and T5 - sum).

Vertical ordinates: tons/ft. of length.

Horizontal " : length (ft.)



(Fig. 2).

With each weight it is necessary to determine the distances of its fore and aft ends from the Z axis through the stern in terms of the number of ship divisions (i.e. L.O.A./100). Fractional parts of such divisions at each end of the weight are calculated and in each case the relevant portion of the weight is then distributed over the whole of the division in which the fractional part lies. See fig. 3. Portions of weight lying wholly across a division are adjusted to be uniform in distribution if not already so, and the weight per foot of length is added to the rearmost ordinate. Since the horizontal lines

drawn between the ordinates of the Weight Distribution Curves are drawn forward from each ordinate respectively, only the rear ordinate of each division is affected by the addition of the weight portion for that division. Ordinate values are a measure of the weight per foot length over that division.

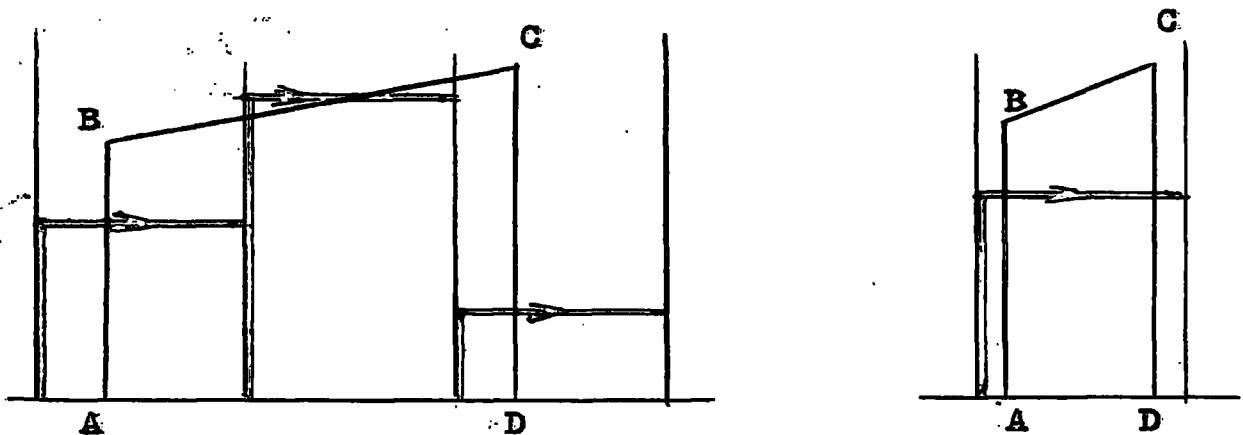
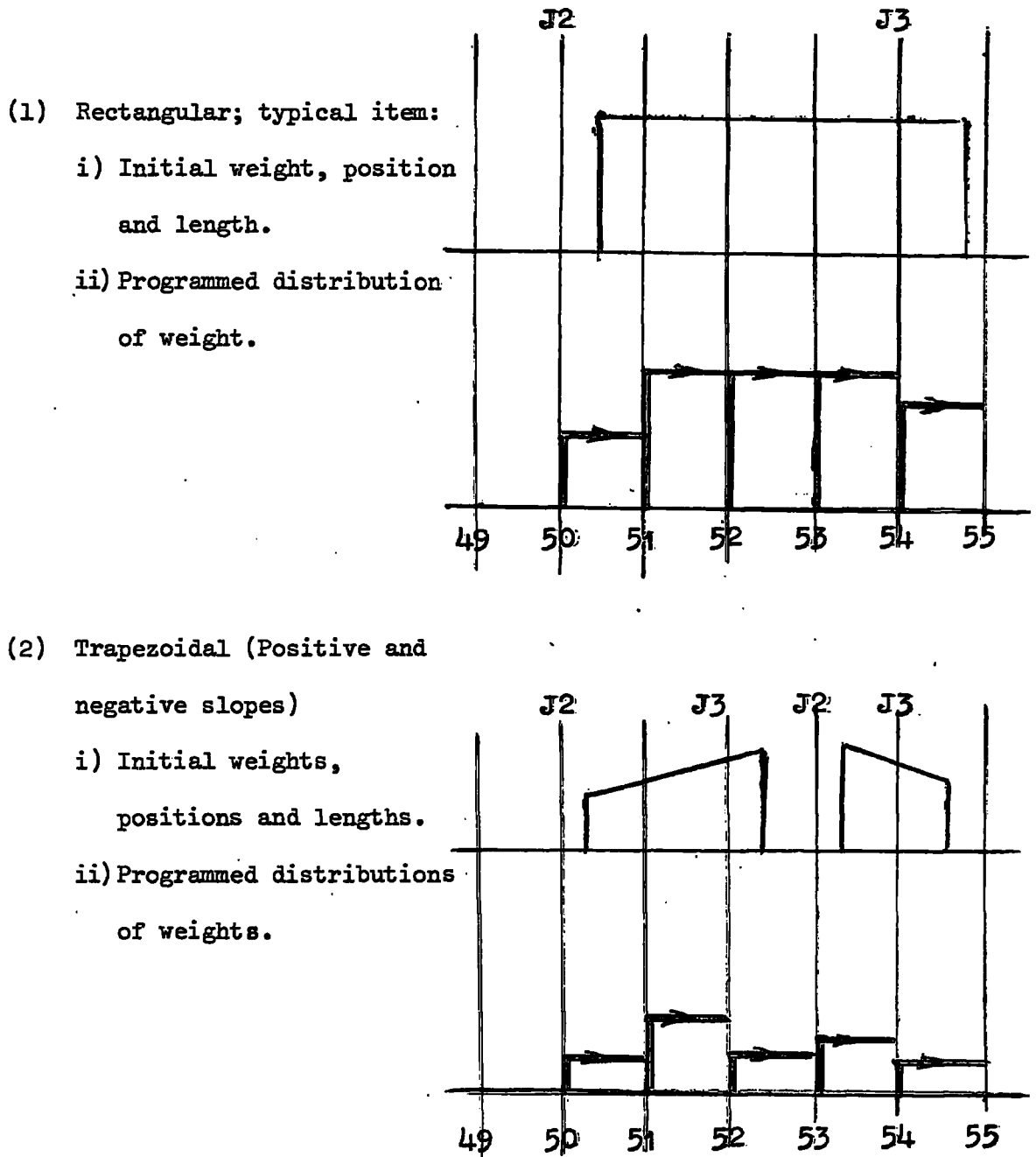


Fig. 3. ABCD - given form for weight item.  
RED lines show the various portions distributed.  
Product of ordinate value and ordinate separation for  
any division gives the weight distributed over that  
division.

It has already been mentioned that two types of weight distributions have been considered; (a) rectangular, (b) trapezoidal, details of which are on pages 13-22. There are thirty possible variations which must be taken into account in programming their distributions. For ease of checking, it has been assumed that each of the test weights lies within and between ordinate numbers 50 and 55, the lengths of the items varying between five full divisions down to part

of one division. Rectangular and trapezoidal distributions are treated separately:



(Fig. 4)

Weights which lie wholly between two adjacent ordinates, no matter what type of distribution, affect only the rearmost ordinate of that division. See pages 13 and 15.

As an example of the manner in which the calculations are performed let us assume two local weights with the following particulars, on a ship whose L.O.A. is 500 ft.

1. Rectangular distribution:

<u>Tons</u>	<u>Ft.</u>	<u>Ft.</u>	<u>Ft.</u>
$W = 36$	$S = 18$	$B = 0$	$X = 262$

(See ex. 30 page 22)

$$\text{L.O.A.} = 500 \text{ ft.} \quad \text{L}/100 = 5 \text{ ft.}$$

Since the distribution is rectangular ( $B = 0$ ), each end of the item is 9 ft. from its centre, which is itself 262 ft. from the stern. Therefore

Dist. of aft end of item from stern = 253 ft.

(i.e.  $253/5$  divs. from stern: i.e. between ordinates 50 and 51)

Dist. of fore end of item from stern = 271 ft.

(i.e.  $271/5$  divs. from stern: i.e. between ordinates 54 and 55).

The portion AB of the weight occupies the foremost 2 ft. of division 50-51. Therefore 4 tons weight lies in this division. (i.e. 2 tons/ft. - original ordinate - over a dist. of 2 ft.) 4 tons spread evenly over the division gives an ordinate value  $\frac{4}{5}$  tons/ft. for division No. 50 - 51.

The forward end E of the weight occupies 1/5 of the division

54 - 55. The portion of weight in this division is, therefore, 2 tons.

This weight spread over the whole division gives an ordinate value 2/5 tons/ft. for division No. 54 - 55.

In each case only the rearmost ordinate of the division is affected since values are 'projected forward'.

Results output would be of the form:

<u>ORD.</u> <u>NO.</u>	<u>WEIGHT</u> <u>TON/FT</u>	<u>ORD.</u> <u>NO.</u>	<u>WEIGHT</u> <u>TON/FT</u>	<u>ORD.</u> <u>NO.</u>	<u>WEIGHT</u> <u>TON/FT</u>	<u>ORD.</u> <u>NO.</u>	<u>WEIGHT</u> <u>TON/FT</u>
				50	0.800	51	2.000
52	2.000	53	2.000	54	0.400		

## 2. Trapezoidal distribution:

$$\begin{array}{cccc} \text{Tons} & \text{Ft.} & \text{Ft.} & \text{Ft.} \\ W = 48 & S = 24 & B = +1 & X = 264 \end{array}$$

(See ex. 19, page 21)

$$L.O.A. = 500 \text{ ft. --- } L/100 = 5 \text{ ft.}$$

The two end ordinates are found from the formulae:-

$$\text{Fwd. end } F = \left( \frac{6(B)}{S} + 1 \right) \frac{W}{S} ; \text{Aft. end } A = \left( \frac{2(W)}{S} - F \right)$$

See page 12 for derivation of formulae.

In the cases where B is negative, F is less than A.



The slope (H) of the upper edge is given by:

$$H = (F - A)/S$$

In our example,  $F = \left[ \frac{6 \times 1}{24} + 1 \right] \frac{48}{24}$  and  $A = \left[ \frac{2 \times 48}{24} - F \right]$

i.e.  $F = \left[ \frac{1}{4} + 1 \right] \times 2 = 2.5 \text{ tons/ft.}$

and  $A = (4 - 2.5) = 1.5 \text{ tons/ft.}$

and slope  $H = \frac{(2.5 - 1.5)}{24} = \frac{1}{24} \text{ tons/ft/ft.}$

The centre of length of the item is (264 - 1) ft. from the stern. Therefore, end A is (263 - 12) ft = 251 ft. from the stern, and fore end F is (263 + 12) ft. = 275 ft. from the stern.

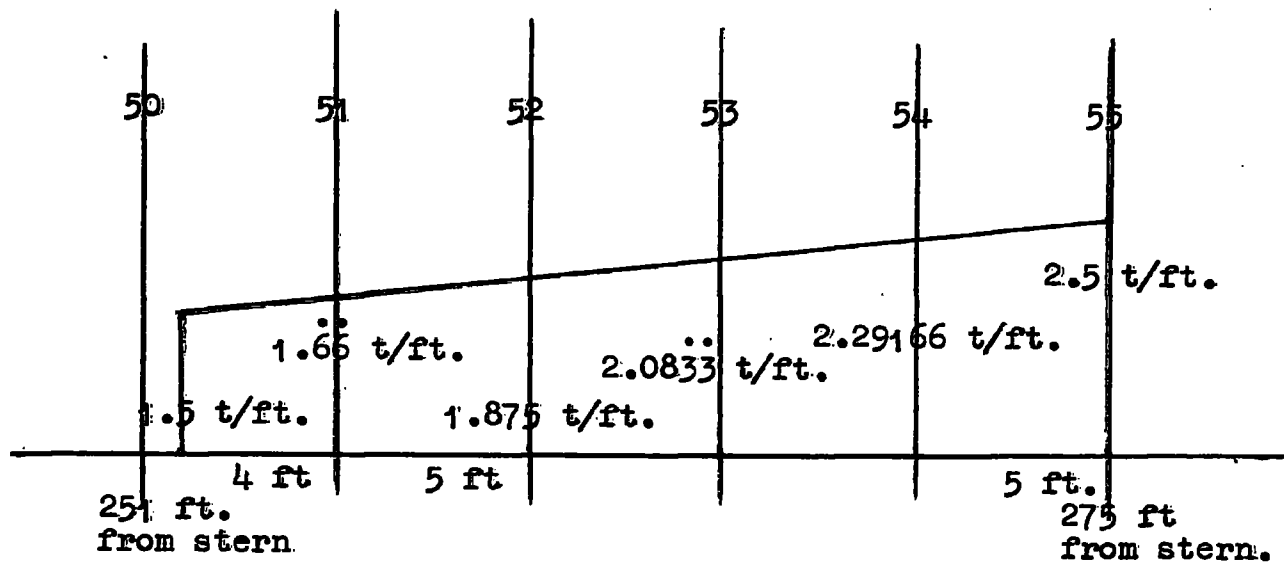
End F is, therefore, coincident with ordinate No. 55, and end A is 1 ft. forward of ordinate No. 50.

Since end A ord. value is 1.5 units, lying 4 ft. aft of ord. 51, the value of ord. 51 is given by  $(1.5 + 4/24) = 1.66 \text{ units.}$

$$\text{Ord. 52} = 1.\ddot{6}\ddot{6} + 5/24 = 1.875$$

$$\text{Ord. 53} = 1.875 + 5/24 = 2.08\ddot{3}\ddot{3}$$

$$\text{Ord. 54} = 2.08\ddot{3}\ddot{3} + 5/24 = 2.291\ddot{6}\ddot{6} .$$

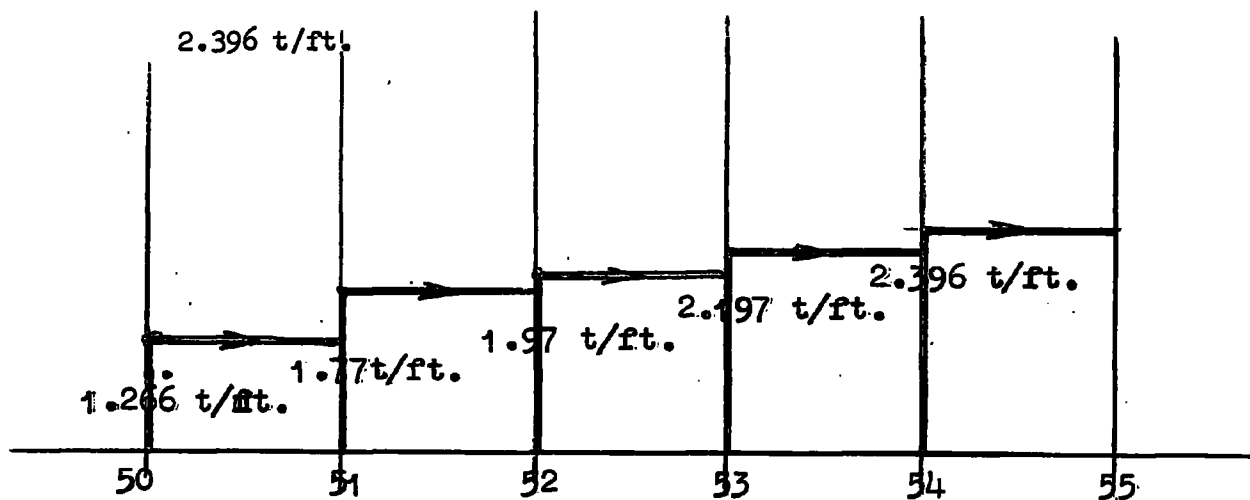


(Fig. 6 (a))

Portion of weight lying in div. 50 - 51 =  $\frac{4}{2} \times (1.5 + 1.66) = 6.33$  ton.

Spread over the whole division, this gives a value for ord. 50 of 1.266 t/ft. (which is, of course, projected forward).

Similarly, ordinate 51 has a value (projected forward) of 1.770833 t/ft., ord. 52 1.979166 t/ft., ord. 53 2.187496 t/ft., and ord. 54 2.396 t/ft.



(Fig. 6 (b))

Results output are as in (1) above for the rectangle.

F.Pt. variable YR (R has all values 0 to 100) is used for ordinate values. On completion, ordinate values are summed (F. Pt. variable S), and the total weight distributed (again S) found by multiplying the sum value by a division length. Summing S in this fashion is effectively the same as producing one total ordinate (units - ton/ft); the product of this ordinate value and the ordinate separation (in feet) gives the total weight. This is printed out under the title

"Calculated Sum of Distributed Local Weights".

---

There follows now all the possibilities of weight distributions, both rectangular and trapezoidal (limited to a maximum size of five divisions purely for the sake of checking - the same principles apply to an item of any larger size.)

As mentioned on page 8, the end ordinates of trapezoidal distributions are given by:

$$F = \frac{W}{S} \left( \frac{6B}{S} + 1 \right) \quad \text{and}$$

$$A = \frac{2W}{S} - F = \frac{2W}{S} - \frac{W}{S} \left( \frac{6B}{S} + 1 \right) = \frac{W}{S} \left( 1 - \frac{6B}{S} \right).$$

These formulae are derived as follows:-

(Using W as a measure of the area)

C.G. of the area is given by

$$D = \frac{S}{3} \left( \frac{A + 2F}{A + F} \right) \text{ from end A.}$$

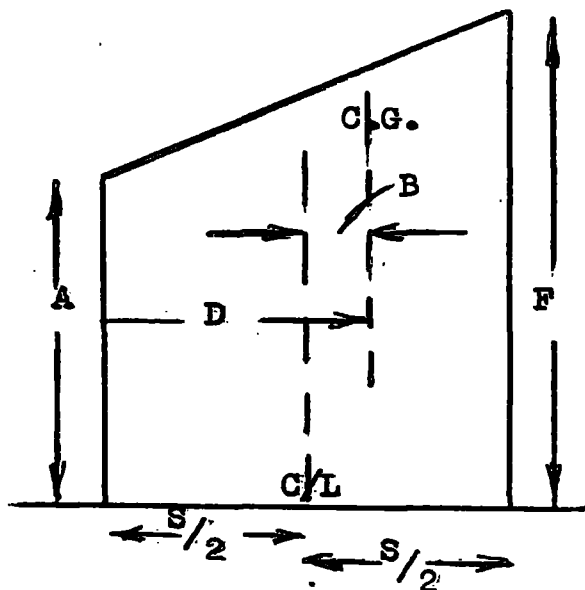
$$\text{i.e. } \frac{\bar{S}}{2} + B = \frac{S}{3} \left( \frac{A + 2F}{A + F} \right) \dots\dots (a)$$

$$\text{Also } W = \left( \frac{A + F}{2} \right) S \dots\dots\dots (b)$$

$$\text{From (b) } A = \frac{2W}{S} - F \text{ and}$$

substituting this in (a) gives

$$F = \frac{W}{S} \left( \frac{6B}{S} + 1 \right).$$



(Fig. 7)

The ordinate immediately preceding, or coincident with the aft end of the item is called J2 (both in the programme and in this exposition). The ordinate coincident with, or immediately aft of the fore end of the item is called J3. In certain instances it will be seen that J2 and J3 are one and the same ordinate. The following are the weight particulars with which the programme was tested. L.O.A. was taken as 500 ft., so that ordinates are 5 ft. apart throughout. Ordinate values are summed, assuming each weight is added in turn.

Details of Local Weights Data, (showing the resultant values on the various ordinates and the graphical interpretation of the distribution. (as given - black; redistributed - red). Values of A and F given over-leaf are not calculated when J2 = J3.) :-

TYPE 1

ITEMS FOR WHICH J2 = J3 (ASSUMED = 50)

	J2	J3	49	50	51	52	W	S	B	X	49	50	51	52
Ex (i)							9	3	0.166	252		1.8		
							A = 2	F = 4				Sl = 1.8		
(ii)							9	3	-0.166	252		1.8		
							A = 4	F = 2				Sl = 3.6		
(iii)							9	3	-0.166	251.33		1.8		
							A = 4	F = 2				Sl = 5.4		
(iv)							9	3	0.166	251.66		1.8		
							A = 2	F = 4				Sl = 7.2		
(v)							9	3	0	252.5		1.8		
							A = F	F = 3				Sl = 9.0		
(vi)							9	3	0	251.5		1.8		
							A = F	F = 3				Sl = 10.8		

TABLE 1.

In the cases listed on page 13, J2 and J3 (which are the integral parts of the numbers of divisions of their fore and aft boundary lines from the stern) are the same, as it can be seen that the whole of each item of weight lies within two adjacent ordinates. It is necessary only to average the weight over the enclosing division. End ordinates A and F are not calculated. These cases are dealt with under Ref. 3 in the programme.

The measure  $w$  to be added to the rearmost ordinate of the two (for local weight item No. 1) is given by  $w = W/L6$  (where  $L6 = L.O.A./100$ ). If J2 be ordinate number R in this case, then the new value of ordinate R is given by:

$$YR = YR + w \quad \text{where } YR \text{ is the resultant ordinate value at any time.}$$

(new value = old value + addition).

e.g. if each of the above items were read into the programme in turn, the final value for ordinate number 50 would be 10.8 ton/ft.

#### TYPE 2

- (a) Items for which  $J3 = J2 + 1$ , where J3 is coincident with the fore end F of the item.

In these cases too, the whole of the weight lies between two adjacent ordinates: again if  $w$  is the measure to be added to the rear-

TYPE 2

(a) ITEMS FOR WHICH  $J3 = J2 + 1$ , WHERE  $J3$  IS COINCIDENT WITH THE FORE END B OF THE ITEM

	49	50	51	52	<u>W</u>	<u>S</u>	<u>B</u>	<u>X</u>	<u>49</u>	<u>50</u>	<u>51</u>	<u>52</u>
Ex(vii)		(J2)	(J3)		9	3	$0.166$	$253.66$		$1.8$ $S1 = 12.6$		
					A = 2		F = 4					
(viii)					9	3	$-0.166$	$253.33$		$1.8$ $S1 = 14.4$		
					A = 4		F = 2					
(ix)					9	3	0	$253.5$		$1.8$ $S1 = 16.2$		
					A = F = 3							
(x)					10	5	0.5	$253$		$2.0$ $S1 = 18.2$		
					A = 0.8		F = 3.2					
(xi)					10	5	-0.5	$252$		$2.0$ $S1 = 20.2$		
					A = 3.2		F = 0.8					
(xii)					10	5	0	$252.5$		$2.0$ $S1 = 22.2$		
					A = F = 2							

TABLE 2

most ordinate, where  $\underline{w} = W/L6$  we have, for ordinate J2

$$YR = YR + w \quad \text{i.e.} \quad Y50 = Y50 + w$$

as before.

Again, values of A and F given overleaf are not calculated in the programme. If  $\underline{w}$  is the measure to be added to the rearmost ordinate, where  $\underline{w} = W/L6$  we have, for ordinate J2 (ordinate number R):

$$YR = YR + w \quad \text{i.e.} \quad Y50 = Y50 + w$$

as before.

Adding each of the above items in turn into the programme would now give a resultant value for ordinate 50 of 22.2 ton/ft.

- (b) Items for which  $J3 = J2 + 1$ , where J3 is not coincident with the fore end of the item.

In these cases the weight does not lie wholly between two ordinates. In examples 13, 14 and 15 there is a fractional part at the fore end, but the aft end coincides with the ordinate J2. In cases 16, 17 and 18 there are fractional parts both fore and aft. Forward fractional parts are labelled F3 and rear fractional parts F2 (both here and in the programme). Ends A and F have to be calculated for this and following types.



TYPE 2

(b.) ITEMS FOR WHICH J3 = J2 + 1, WHERE J3 IS NOT COINCIDENT WITH THE FORE END OF THE ITEM

	J2	J3	W	S	B	X	49	50	51	52
(xiii)	50	51	24	6	0.5	253.5		3.668	1.14	
			A = 2:	F = 6				S1 = 25.868	S1 = 1.14	
(xiv)	50	51	24	6	-0.5	252.5		4.332	0.464	
			A = 6:	F = 2				S1 = 30.200	S1 = 1.604	
(xv)	50	51	24	6	0	253		4.000	0.800	
			A = F = 4					S1 = 34.200	S1 = 2.404	
(xvi)	50	51	24	6	0.5	255.5		1.800	3.000	
			A = 2:	F = 6				S1 = 36.000	S1 = 5.404	
(xvii)	50	51	24	6	-0.5	254.5		3.000	1.800	
			A = 6:	F = 2				S1 = 39.000	S1 = 7.204	
(xviii)	50	51	24	6	0	255		2.400	2.400	
			A = F = 4					S1 = 41.400	S1 = 9.604	

TABLE 3.

In rectangular distributions where  $J_3 = J_2 + 1$ :-  
 The original height of the rectangle is given by  $A = W/S$ .  
 The weight spread over the fractional distance  $F_3$  is,  
 therefore,  $F_3 \times A$ , and the measure to be added to the  
 $J_3$  ordinate is given by  $A_3 = (F_3 \times A)/L_6$ .

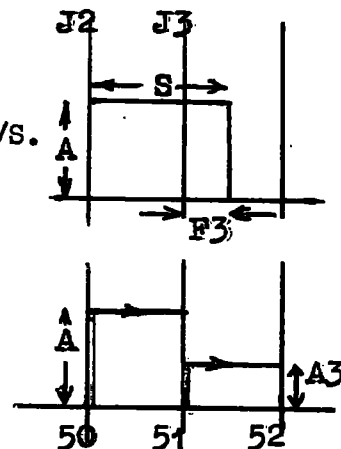


Fig. 8.

-If R then, is the ordinate number of  $J_3$  we have, by the additon  
 of this weight

$$YR = YR + A_3.$$

$$\text{e.g. } Y_{51} = Y_{51} + A_3.$$

Where  $F_2 = 0$  (Fig. 8), and the ordinate  $J_2$  has number R, then the new  
 value for ordinate  $J_2$  is given by

$$YR = YR + A.$$

$$\text{e.g. } Y_{50} = Y_{50} + A.$$

Where  $F_2 \neq 0$  (Fig. 9), then the portion of weight over  $F_2$  is given by  
 $A_2 = F_2 \times A$ , and this spread over the whole division gives a final  
 value  $A_2$  where

$$A_2 = (F_2 \times A)/L_6.$$

Again if R is the number of ordinate  $J_2$  then the new value of the  
 ordinate is given by

$$YR = YR + A_2.$$

$$\text{e.g. } Y_{50} = Y_{50} + A_2.$$

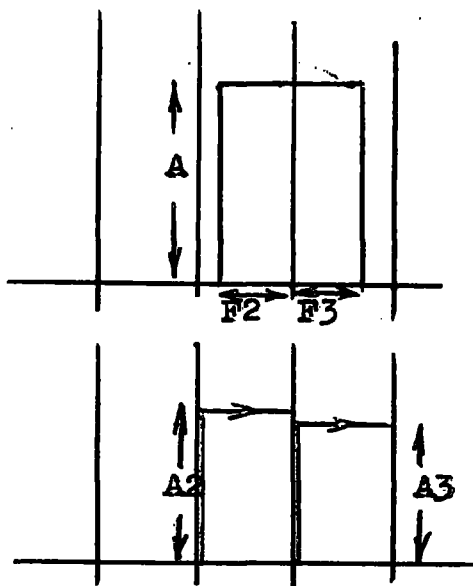


Fig. 9.

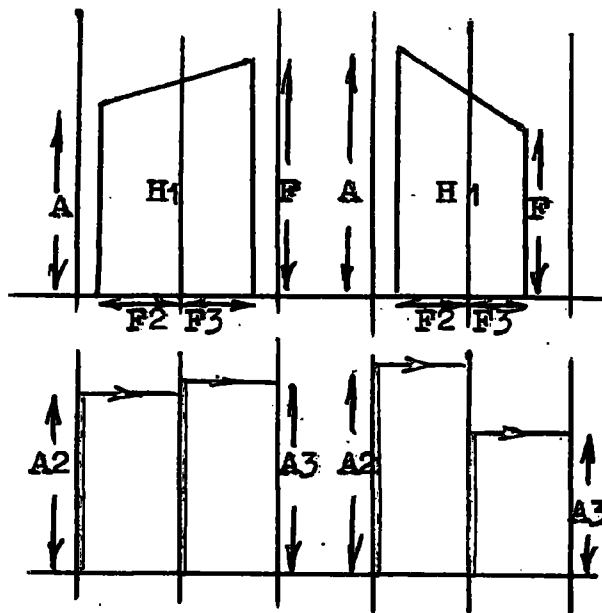


Fig. 10.

Where the weight distribution is a trapezium, A may be greater or less than F. The slope of the upper edge is always H in the programme, whether positive (A less than F) or negative (A greater than F). In examples 13, 14, 16 and 17 above the height H1 can be found from end F, the slope of the upper edge H, and the distance F3. Fig. 10.

The weight of the fractional part forward of J3 is now given by

$$A3 = (H3 + H1) \cdot F3/2$$

and spread over the whole division we have the value to be added to ordinate J3 given by A3 where A3 now has a new value:

$$A3 = \frac{H3 + H1}{L6} \cdot \frac{F3}{2}$$

If J3 is number R, then the new value of YR is given by

$$YR = YR + A3.$$

$$\text{e.g. } Y51 = Y51 + A3.$$

### TYPE 3

#### Items for which J3 - J2 is greater than 1.

The method above is used to find the fractional areas adjacent to J2 and J3. The remaining area which extends over one or more full divisions is treated as in the examples given on pages 21, 22. In the following examples J3 - J2 is taken to be 5, for the sake of uniformity. All possible cases are dealt with. (Figs. showing graphical output will now be discontinued).

\* \* \* \*

Page 24 to 28 shows the completed data sheets giving details of local weights for A.842.

Page 29 indicates the type of heading output before the tabulated results for weight, buoyancy, etc. Offending items, if any, in Local Weights lists (see page (iii) intro.) are output before all other headings.

Page 30 shows the tabulated output for the data of pages 24 to 28 and page 31 shows the output on the Benson-Lehner graph plotter for these results.

TYPE 3

ITEMS FOR WHICH J3 - J2 IS GREATER THAN 1

	49	50 (J2)	51	52	53	54	55 (J3)	56	W	S	B	X	50	51	52	53	54
Ex (xix)									48	24	1	264	1.267	1.771	1.980	2.188	2.396
									Sums = 25.267					4.172	1.980	2.188	2.396
									A = 1.5 ; F = 2.5								
(xx)									28	24	-1	262	1.933	2.229	2.021	1.812	1.604
									Sums = 27.200					6.401	4.001	4.000	4.000
									A = 2.5 ; F = 1.5								
(xxi)									48	24	0	263	1.600	2.000	2.000	2.000	2.000
									Sums = 28.800					8.401	6.001	6.000	6.000
									A = F = 2								
(xxii)									48	24	1	263	1.604	1.812	2.021	2.229	1.933
									Sums = 30.404					10.213	8.022	8.229	7.933
									A = 1.5 ; F = 2.5								
(xxiii)									48	24	-1	261	2.396	2.188	1.980	1.771	1.267
									Sums = 32.800					12.401	10.002	10.000	9.200
									A = 2.5 ; F = 1.5								
(xxiv)									48	24	0	262	2.000	2.000	2.000	2.000	1.600
									Sums = 34.800					14.401	12.002	12.000	10.800
									A = F = 2								

TABLE 4.

TYPE 3 (contd)

ITEMS FOR WHICH J3 - J2 IS GREATER THAN 1.

	49	50 (J2)	51	52 C/L 262.5	53	54	55 (J3)	56	<u>W</u>	<u>S</u>	<u>B</u>	<u>X</u>	<u>50</u>	<u>51</u>	<u>52</u>	<u>53</u>	<u>54</u>
Ex (xxv)									50	25	1.5	264	1.424	1.712	2.000	2.288	2.576
									Sums = 36.224				16.113	14.002	14.288	13.376	
									A = 1.28; F = 2.72								
(xxvi)									50	25	-1.5	261	2.576	2.288	2.000	1.712	1.424
									Sums = 38.800				18.401	16.002	16.000	14.800	
									A = 2.72; F = 1.28								
(xxvii)									50	25	0	262.5	2.000	2.000	2.000	2.000	2.000
									Sums = 40.800				20.401	18.002	18.000	16.800	
									A = F = 2								
(xxviii)									36	18	1.5	263.5	0.444	1.499	2.056	2.611	0.589
									Sums = 41.244				21.899	20.058	20.611	17.389	
									A = 1 ; F = 3								
(xxix)									36	18	-1.5	260.5	1.156	2.500	1.944	1.389	0.211
									Sums = 42.400				24.399	22.002	22.000	17.600	
									A = 3 ; F = 1								
(xxx)									36	18	0	262	0.800	2.000	2.000	2.000	0.400
									Sums = 43.200				26.399	24.002	24.000	18.000	
									A = F = 2								

TABLE 5.

Tape 1. (Required for FIRST data run only).

If some (or all) conditions are to be re-run in order to graph all Shear Force curves to the same scale (and similarly the Bending Moment curves), from the maximum values determined on a previous run, PUT 13 = 1.

IN ALL OTHER CASES, PUT 13 = 0.

Programme  
Variable.

0	13
---	----

If 13 = 0, omit this section, and go on to the next section.

If 13 = 1, enter the appropriate maximum values from the previous runs. (If either one is not required, enter two zeros for that curve).

Maximum Shear Force (+ve) tons		S25
" " " (-ve) "		S26
Maximum Bending Moment (+ve) tons/ft.		M6
" " " (-ve) " "		M7

(PROGRAMME WAIT HERE)

0 for Lloyd's method: 1 for Biles Coffin	0	I1
Length Overall ft.	617	L
Length of Stern Overhang "	23	L1
Length of Bow Overhang "	14	L2

Enter 1 for full width graph, 0.5 for half width graph or 0 for no graph	1	S22
Horizontal Scale required (Convenient choice : 10, 20 or 40 - ft/cm.) Enter 0 if no graph required.	20	S27

Code Number for Lightship Concentrated Items	0	P4
Number of Concentrated Lightship Items	71	N

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
Lower Bridge & Hse Below	75.17	94.50	-	81.75
Upper " " "	58.96	90.00	-	83.00
Boat " " "	47.09	78.50	-	88.25
Nav. Bridge " "	15.65	32.75	-	110.38
Wheel House	12.50	25.00	-	126.50
No. 1 Hatch	26.21	36.00	-	536.25
" 2 "	26.30	36.50	-	487.50
" 3 "	12.76	17.50	-	432.75
" 4 "	27.35	37.50	-	380.25
" 5 "	27.35	37.50	-	317.75
" 6 "	12.76	17.50	-	265.25
" 7 "	27.35	37.50	-	220.25
" 8 "	27.35	37.50	-	157.75
" 1 Hatch Cover Tracks	2.42	6.00	-	559.25
" 2/3 " " Post & Tracks	4.65	17.50	-	451.00
" 4/5 " " " "	5.87	25.00	-	349.00
" 6/7 " " " "	4.65	17.50	-	247.75
" 8 " " Tracks	2.42	6.00	-	136.00
" 1 Masthouse, Winches, etc.	28.30	15.75	-	508.13
" 2 " " "	27.90	15.00	-	411.50
" 3 " " "	27.90	15.00	-	286.50
" 4 " " "	27.90	15.00	-	189.00
" 1 Masthouse Derrick Posts, Derricks etc.	15.50	2.50	-	508.13
" 2 " " " "	15.50	2.50	-	411.50
" 3 " " " "	15.50	2.50	-	286.50
" 4 " " " "	15.50	2.50	-	189.00
Windlass	12.00	9.00	-	577.75
Anchors	11.63	6.00	-	592.50
Anchor Chain	59.95	8.00	-	576.00
Fcle. Dk. Ftgs. Bollards etc.	6.10	51.00	-8.50	580.0

\* -ve if aft of Centre of Length.



ITEM	Weight (tons) (A)	Length (ft) (B)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
Up.Dk.Aft. Fittings, Winch, etc.	16.00	34.50	5.75	23.00
Funnel	19.61	28.00	1.00	84.50
Lifeboats and Davits	7.50	26.00	-	87.50
Sternframe	22.40	19.00	2.00	33.00
Propeller	16.30	6.00	-	30.50
Rudder and fittings	10.20	12.25	-	20.38
Steering Gear	6.50	7.25	-	23.00
Upholstery	3.10	91.00	-	83.75
Deck Coverings etc.	30.00	91.00	-	83.75
Refrig. Machinery	3.50	6.00	-	48.00
Domestic Refrig. Insulation	13.00	19.50	1.75	46.00
Windows and Doors (Accom.)	10.00	91.00	-	83.75
Piping (Accom.)	12.00	91.00	-	83.75
Smithwork and Rivs.	35.00	580.00	-	313.00
Electrodes	85.75	580.00	-	313.00
Paint	20.00	580.00	-	313.00
Piping (Holds)	45.00	448.00	-	348.00
Main Engine	376.00	28.50	-1.33	95.42
Generators	42.60	16.33	-	61.50
Auxiliaries Incl. Seats.	258.47	80.00	12.43	96.43
Shafting and Bearings	26.43	40.00	-	54.00
Stern tube	6.00	10.00	-	39.00
E.R. Flat 25'-0" A.B.	42.36	80.00	-	84.00
" " 38'-3" "	40.80	80.00	-	84.00
House Front and Side Screens	69.18	98.50	34.00	113.25
Fcle.Dk. Stores & Fore End Bulw.	34.00	51.00	-8.50	580.00
Radar Mast and Fittings	1.50	4.00	1.00	110.50
Spare Prop.	15.45	18.25	-	60.00
" Tailshaft	11.50	16.75	-	59.00
" Anchor	5.81	8.00	2.50	416.50

\* -ve if aft of Centre of Length.

\* -ve if aft of Centre of Length.

TAPE 2

Programme  
Variable.

Code number for this Sheet - i.e. Condition Number. (1, 2, 3, ... etc.)	1	P4
Number of DEADWEIGHT Items for this condition	36	N

DEADWEIGHT ITEMS

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
W.B. in No. 1 D.B. Tank (Across)	436.00	63.00	-3.87	536.63
" " 2 " " P & S	726.00	65.00	-1.34	475.16
" " 3 " " P & S	1162.00	95.00	.13	396.63
" " 4 " " P & S Outer	668.00	95.00	1.12	302.62
" " 4 " " P & S Inner	486.00	95.00	-.01	301.49
" " 1 Saddle Tank P & S	824.00	112.25	-5.00	495.12
" " 2 " " P & S	700.00	95.00	-	396.50
" " 3 " " P & S	700.00	95.00	-	301.50
" " 4 " " P & S	478.00	65.00	-	221.50
" " Fore Peak	454.00	31.70	-5.43	582.42
" " After Peak	290.00	20.00	2.16	35.16
" " No.3 Hold (Deep Tk.)	2738.00	30.00	-.08	429.08
" " No.6 Hold ( " " )	2738.00	30.00	-.08	268.92
Heavy Oil in No.5 D.B.Tk.P&S Inner	233.24	65.00	-	221.50
" " " " 5 " " " Outer	348.88	65.00	2.62	224.12
" " " " 6 " " Port	194.04	67.50	3.60	158.85
" " " " 6 " " Starb.Outer	133.28	67.50	5.47	160.72
" " " " 5 Saddle Tk. P & S	415.52	65.00	.31	156.81
" " " Tank Aft. Clean Sett.	20.58	6.25	-	89.63
" " " " " " " Fwd.	20.58	6.25	-	95.88

\* -ve if aft of Centre of Length.



SHIPYARD A.

SHIP NO. 842

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION 1, BALLAST DEPARTURE  
FULL BUNKERS.

STILL WATER.

LENGTH OVERALL : 617.00 FT

SUM OF LIGHTSHIP LOCAL WEIGHTS READ IN = 2476.86 TONS

SUM OF EXTRA LOCAL WTS. FOR THIS CONDITION, READ IN = 14209.65 TONS

CALCULATED SUM OF DISTRIBUTED LOCAL WEIGHTS = 16686.51 TONS

CONTINUOUS WEIGHT TOTAL FOR LLOYDS' DISTRIBUTION = 4632.14 TONS

CALCULATED "M" -TONS/FT = 9.359

CALCULATED L.C.G. OF CONTINUOUS WEIGHT = 311.32 FT.

NOTE: ORDINATES IN THE FOLLOWING TABLES ARE NUMBERED FROM THE  
STERN (ORDINATE NO. 0) TO THE BOW (ORDINATE NO. 100).

SHIPYARD A.

SHIP NO. 842

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD).

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.08	1	0.25	2	0.99	3	4.14
4	14.04	5	24.10	6	29.72	7	8.47
8	11.29	9	13.31	10	15.21	11	12.63
12	12.51	13	23.12	14	30.15	15	29.60
16	28.05	17	28.07	18	17.92	19	15.27
20	20.18	21	12.50	22	13.34	23	13.51
24	12.95	25	13.33	26	13.70	27	14.07
28	14.16	29	15.17	30	26.55	31	17.15
32	16.06	33	16.79	34	17.04	35	17.28
36	17.53	37	17.78	38	17.90	39	17.81
40	18.05	41	109.27	42	112.11	43	111.57
44	110.60	45	121.97	46	29.45	47	20.98
48	20.23	49	20.63	50	20.69	51	20.76
52	20.82	53	20.89	54	20.72	55	20.52
56	28.05	57	20.09	58	20.31	59	20.61
60	20.62	61	20.64	62	20.65	63	20.66
64	20.43	65	20.93	66	24.42	67	116.09
68	112.10	69	112.04	70	111.45	71	122.17
72	22.20	73	21.73	74	21.12	75	20.50
76	20.71	77	20.27	78	9.79	79	19.31
80	18.84	81	19.99	82	28.60	83	17.26
84	16.14	85	15.42	86	14.71	87	13.99
88	13.28	89	12.44	90	6.98	91	6.50
92	19.23	93	34.30	94	20.22	95	14.83
96	9.18	97	2.44	98	0.19	99	0.03
100	0.00						

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD)  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

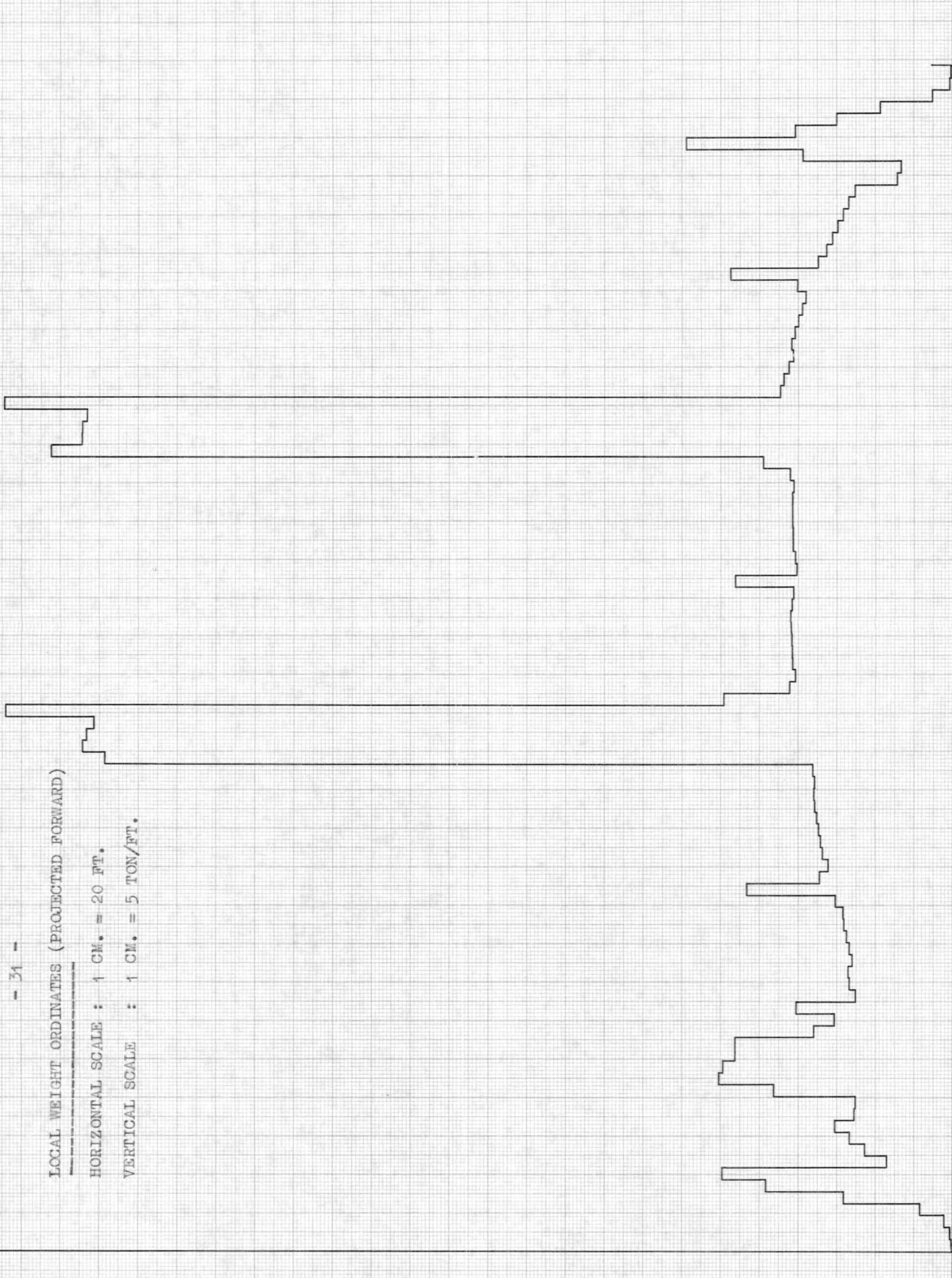
HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0  
-----

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD)

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 5 TON/FT.



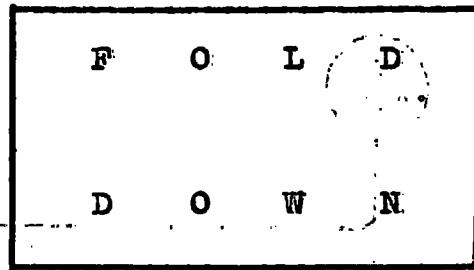


FLOW CHART

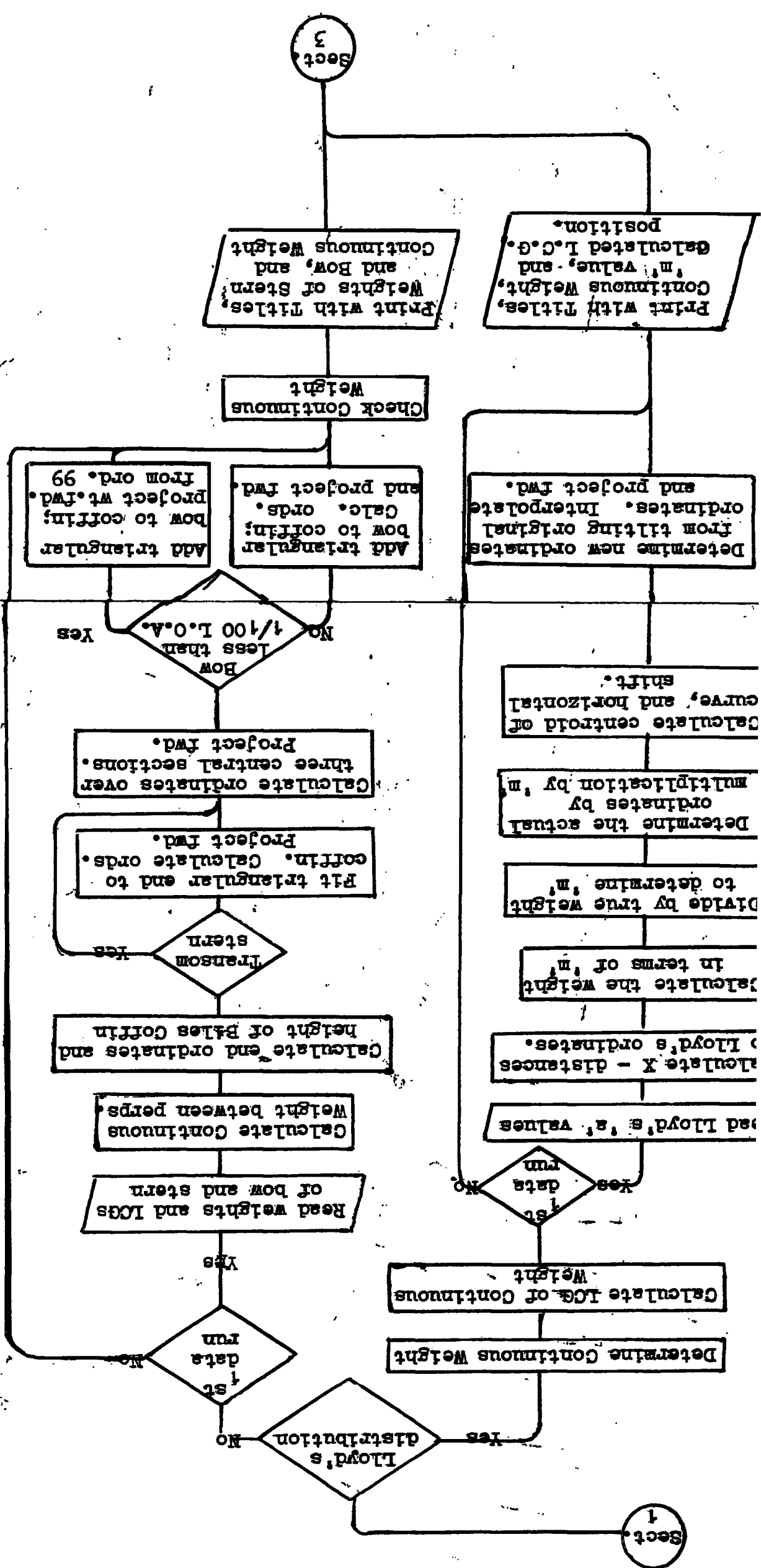
(Section 2).

C O N T I N U O U S

W E I G H T S E C T I O N



CONTINUOUS WEIGHT SECTION (2)



PART 2

(a) BILES' COFFIN CONTINUOUS

WEIGHT DISTRIBUTION

The continuous weight of that portion of the ship which lies between the perpendiculars (i.e. the full weight less the sum of the local weights and less the weights of stern and bow overhangs - programmed W32) is distributed over three equal divisions of the length between the perpendiculars ( $L_{BP}$ ), such that end ordinates A and B are given by the formule:

$$\frac{W_{32}}{L_{BP}} \left( 0.6 \pm \frac{54.k}{7L_{BP}} \right)$$

such that B takes the + sign, and where k is the distance of the L.C.G. of the continuous weight from midships. A is the rearmost ordinate and B the forward ord. in all cases.

If the L.C.G. is forward of midships, k is positive, and the forward ordinate (that at the F.P.) is the larger. If, however, k is to the rear of the midships, then k is itself negative, and A (the ordinate at the A.P.) is the larger. (See fig. 11)

C' and D' divide the length between the perpendiculars into three equal parts. CD is a horizontal line joining the ordinates at C' and D', each having a value given by:

$$CC' = DD' = 1.2 \left( \frac{W_{32}}{L_{BP}} \right) .$$

The stern and bow sections are represented by the triangular ends to the figure.

The total length of the ship (L.O.A.) is divided as before into 100 equal parts, and the weight ordinate at each division mark is calculated using straight line equations.

Ordinate values are amended by taking averages, as before, so that the weight distribution over each division (L6) may be represented by horizontal lines drawn forward from the rear ordinate of each division. No. 99 is the last ordinate with a value.

Floating point variables VR - (0 to 100) are used for ordinate values in this part of the programme.

Output of the table of values is again optional, as in part one; graph output is also optional.

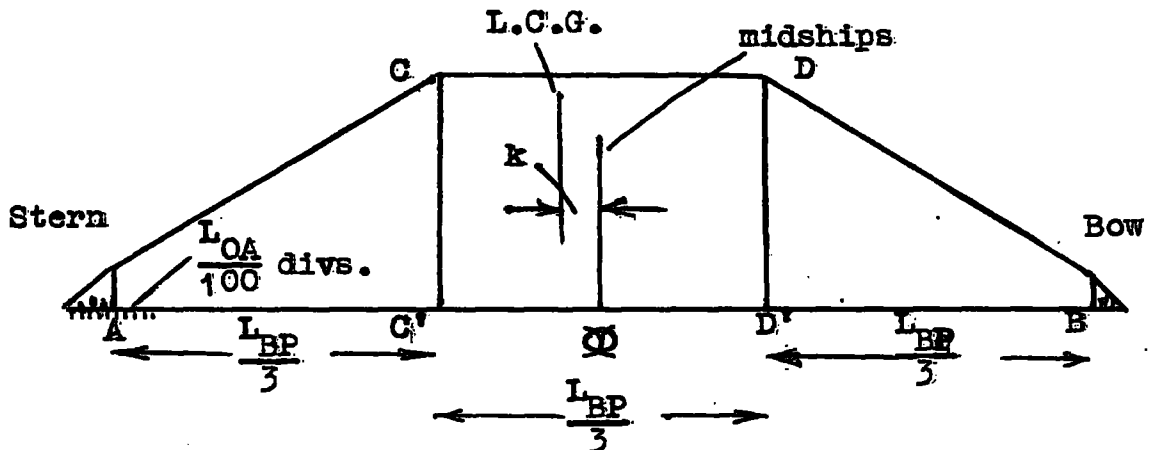


Fig. 11.

Biles Coffin distribution of Continuous Weight.

Note: k -ve and A greater than B.

Page 36 shows the input data when using Biles Coffin method for the distribution of the continuous material of A.842.

Tabulated output for this method is shown on page 37 and the corresponding graph output on page 38.

The use of Biles Coffin method may produce errors in the calculated weights of the overhangs of the bow and stern. In the initial design stages, at which time the actual end values may not be known, this is acceptable.

These errors (as with those which would occur using Lloyd's suggested end lengths - See Table 10, page 61) are corrected in the total weight section, by the technique known as "swinging the base" - See page 63.

TITLE output at Head of Results

= crlf<sup>4</sup>

Name of firm

SHIPYARD A.	Ship No. 842
-------------	--------------

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION No. 1.  
BALLAST DEPARTURE  
FULL BUNKERS

*STILL WATER * <del>SINE/WAVE</del> SAGGING * <del>SINE/WAVE</del> HOGGING	(delete those * not Required).
--	--------------------------------------

Programme  
Variable.

Displacement	21318.65	W31
L.C.G. forward of Stern	321.79	K3

Tape 2 (Contd). (This part of Tape 2 not required after the first data run).

If Continuous Weight is to be distributed by Biles Coffin method, complete lines (a), (b), (c), (d) below, otherwise complete (e) from Lloyds tables SR 64/15.

Programme  
Variable.

For FIRST data run only:

(a) Weight of Overhang of Stern. (tons)	49.37	W33
(b) Weight of Overhang of Bow. (tons)	7.67	W34
(c) L.C.G. of Overhang of Stern, from Stern. (ft)	17.5	L4
(d) L.C.G. of Overhang of Bow, from Stern. (ft)	608.5	L5

(e) For FIRST data run only:

	Stn. 0	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6
0							
Stn. 7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Stn.13	Stn.14
Stn.15	Stn.16	Stn.17	Stn.18	Stn.19	Stn.20		
						0	

SHIPYARD A.

SHIP NO.842

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.75	1	2.25	2	3.75	3	5.20
4	5.69	5	5.81	6	5.93	7	6.06
8	6.18	9	6.31	10	6.43	11	6.55
12	6.68	13	6.80	14	6.92	15	7.05
16	7.17	17	7.29	18	7.42	19	7.54
20	7.67	21	7.79	22	7.91	23	8.04
24	8.16	25	8.28	26	8.41	27	8.53
28	8.65	29	8.78	30	8.90	31	9.03
32	9.15	33	9.27	34	9.40	35	9.47
36	9.47	37	9.47	38	9.47	39	9.47
40	9.47	41	9.47	42	9.47	43	9.47
44	9.47	45	9.47	46	9.47	47	9.47
48	9.47	49	9.47	50	9.47	51	9.47
52	9.47	53	9.47	54	9.47	55	9.47
56	9.47	57	9.47	58	9.47	59	9.47
60	9.47	61	9.47	62	9.47	63	9.47
64	9.47	65	9.47	66	9.43	67	9.27
68	9.09	69	8.91	70	8.73	71	8.55
72	8.38	73	8.20	74	8.02	75	7.84
76	7.66	77	7.48	78	7.31	79	7.13
80	6.95	81	6.77	82	6.59	83	6.41
84	6.23	85	6.06	86	5.88	87	5.70
88	5.52	89	5.34	90	5.16	91	4.99
92	4.81	93	4.63	94	4.45	95	4.27
96	4.09	97	3.86	98	2.56	99	2.13
100	0.00						

Table 7.



CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

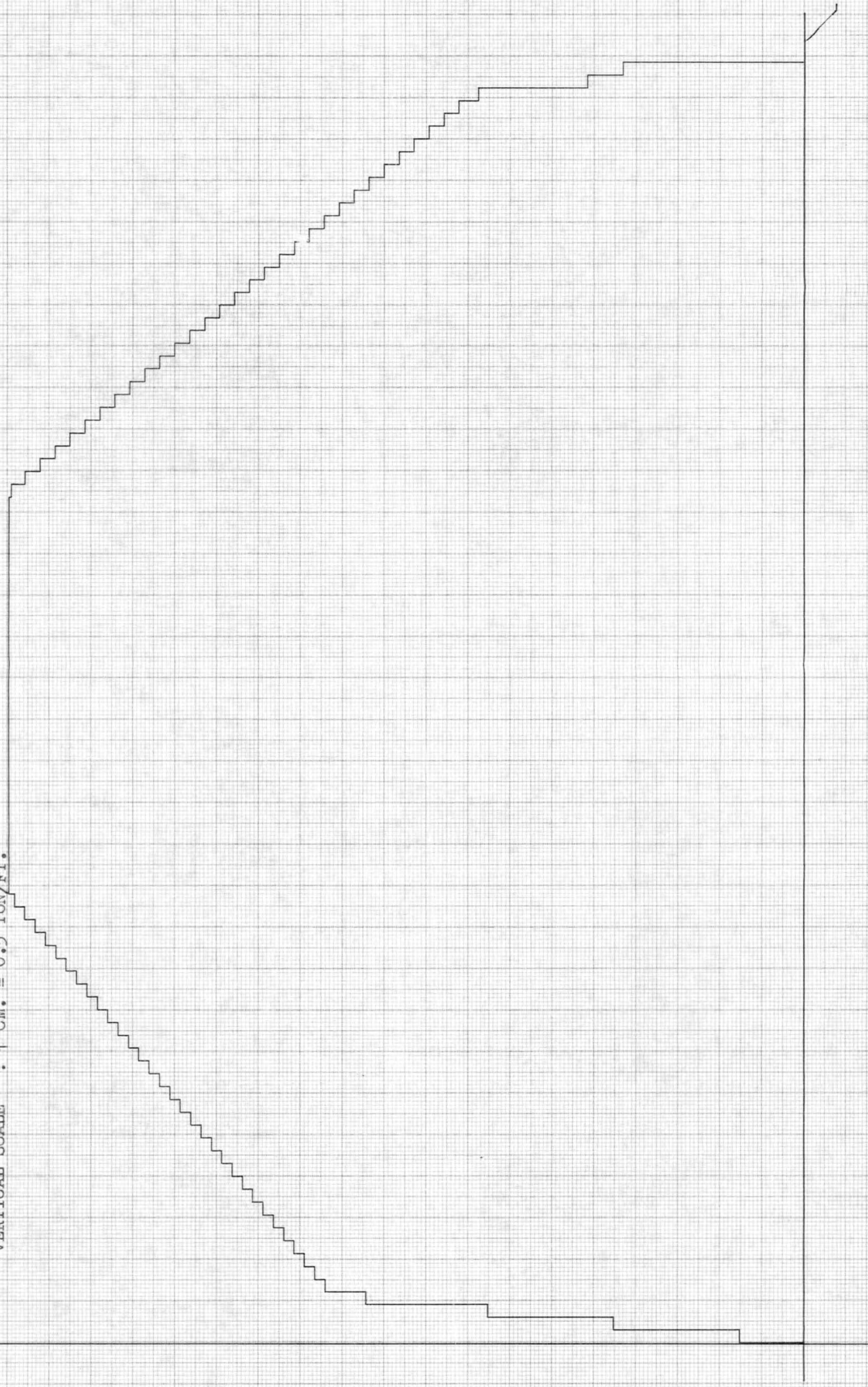
VERTICAL SCALE OF GRAPH --- UNITS/CM:- 0.5  
-----

CONTINUOUS WEIGHT ORDINATES (PROJECTED FORWARD)

(Biles Coffin)

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 0.5 TON/FT.



PART 2

(b) CONTINUOUS WEIGHT DISTRIBUTION

ACCORDING TO LLOYD'S REPORT SR 64/15

This is not the same continuous weight as is used in the Biles Coffin distribution; in this instance it includes the stern and bow sections. It is programmed as W32, and is obtained immediately after reading in the displacement (W31) by subtracting from it the calculated sum of the distributed local weights (S).

The distribution of this weight is considered to be a continuous curve over the whole length of the ship. The curve depends on the block coefficient at the load draught, and has the form shown below, fig.12a, where ordinates 0 to 20 are read from a set of curves produced by Lloyd's Register of Shipping.

These ordinates are called 'a' values, where a has a maximum value of unity. The true ordinate values for the weight curve are given by  $a_i \times m$  ton/ft., where m is the measure in tons/ft. of the midship section, and i has values 0 - 20.

Lloyd's curves are reproduced on pages 42 and 43.

Note the end value suggested by Lloyd's and indicated in Fig. 12 (a).

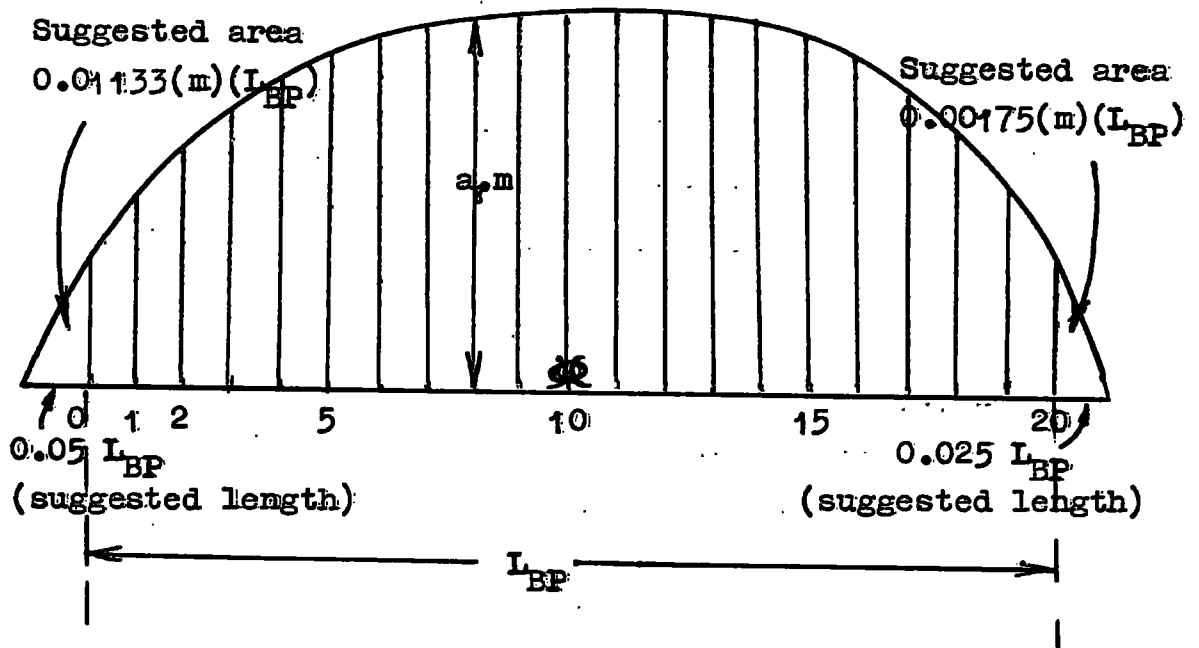


Fig. 12 (a)

Consider the ship under review. Block coefficient ( $C_B$ ) given by the builder as 0.776. Reading from the given curves obtain the 'a' values as follows:

Section	'a' reading	Section	'a' reading	Section	'a' reading
0	0.340	1	0.495	2	0.625
3	0.727	4	0.815	5	0.884
6	0.940	7	0.976	8	0.998
9	1.000	10	1.000	11	1.000
12	1.000	13	1.000	14	1.000
15	1.000	16	0.975	17	0.903
18	0.766	19	0.505	20	0.14

Each of these ordinates must be multiplied by  $\underline{m}$  such that the total weight found by integrating the curve is equal to the continuous weight. This is done by first of all integrating the curve in terms of 'm', and dividing this value into the known continuous weight (W32). This gives the value of  $\underline{m}$ , and ordinate values 'a' are then multiplied throughout by  $\underline{m}$ , to give the true weight/ft. ordinates. (The term 'a' values now incorporates 'm').

The curve is now true so far as weight representation is concerned but does not necessarily yield the true position of the L.C.G. of the continuous weight. The L.C.G. of the vessel for any given loaded condition having been given by the builder, together with the various values of weight and L.C.G. for each of the local weights, it is a simple matter to determine the L.C.G. of the continuous weight by addition and subtraction of moments. This done, it is unlikely that its position will coincide with the calculated L.C.G. of the given curve.

Before further analysis, correction must be made for any discrepancy between calculated and given L.C.G.'s. If the curve had been incorrect for both weight and L.C.G. it could have been corrected by raising (or lowering) the base - known as 'swinging the base'. However, this causes non-zero readings, in general, for ordinates 0 and 100, which may be either positive or negative.



# Values of 'd' for After Body

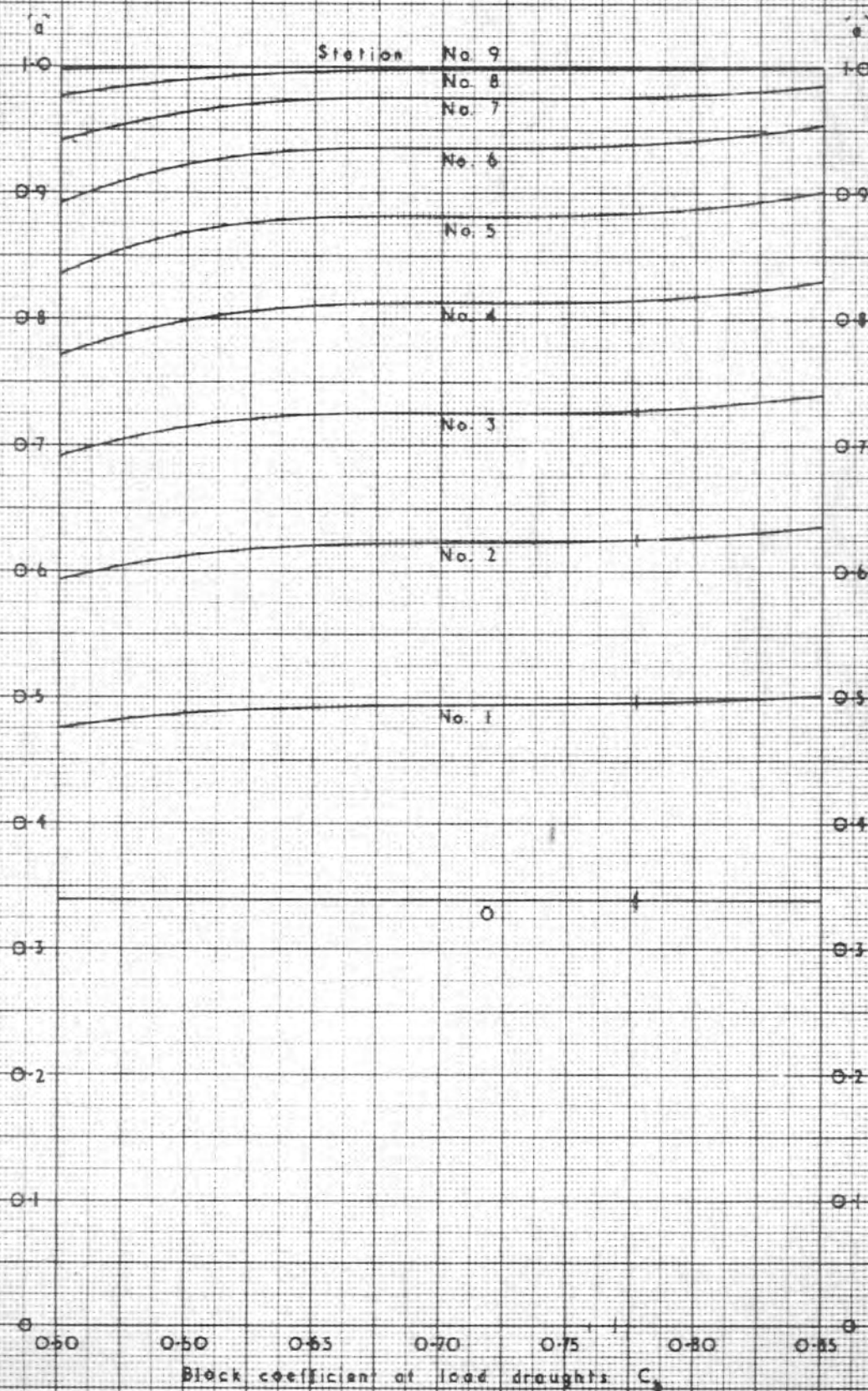


Fig. 3

Values of  $a$  for Fore Body

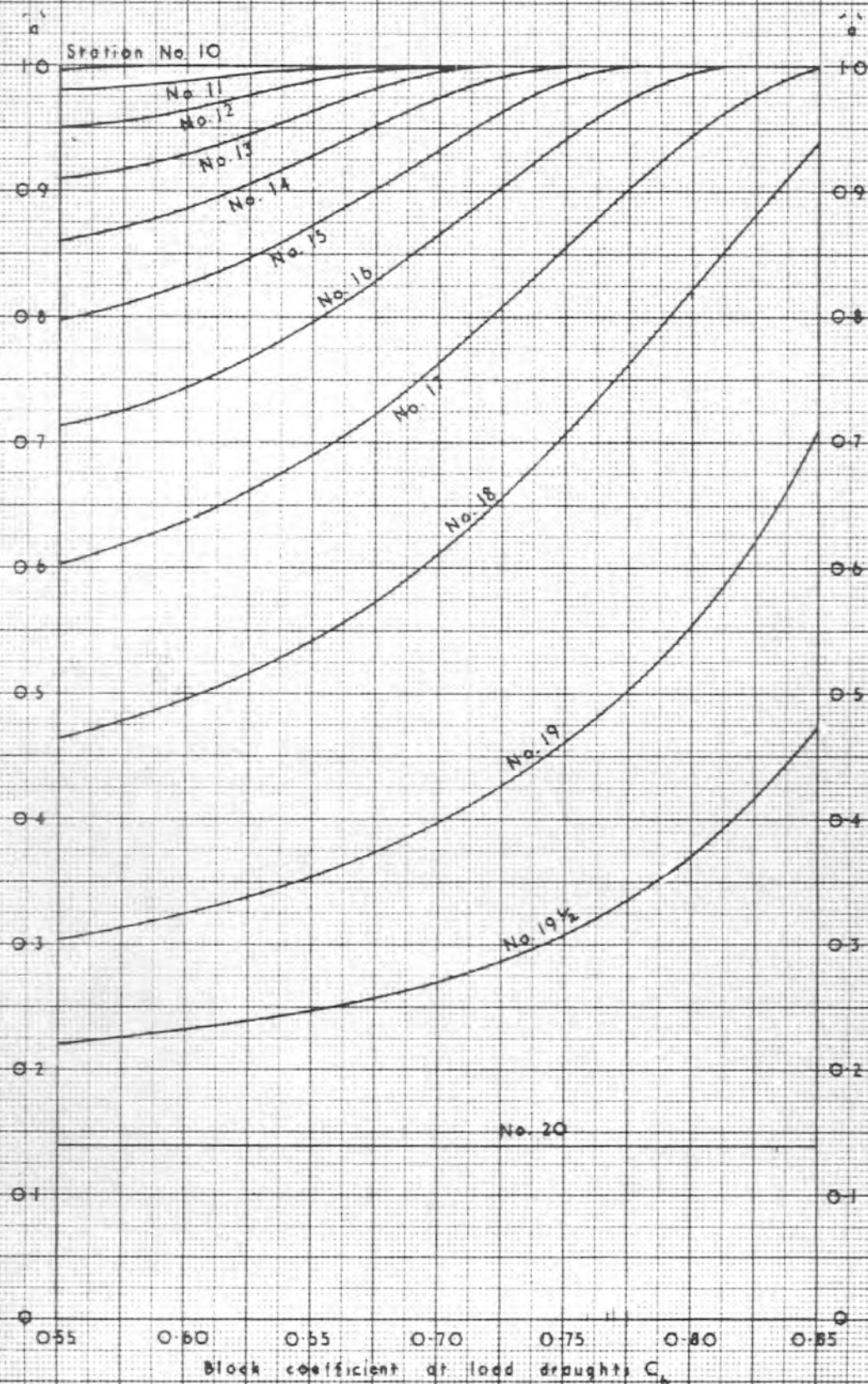


Fig. 4

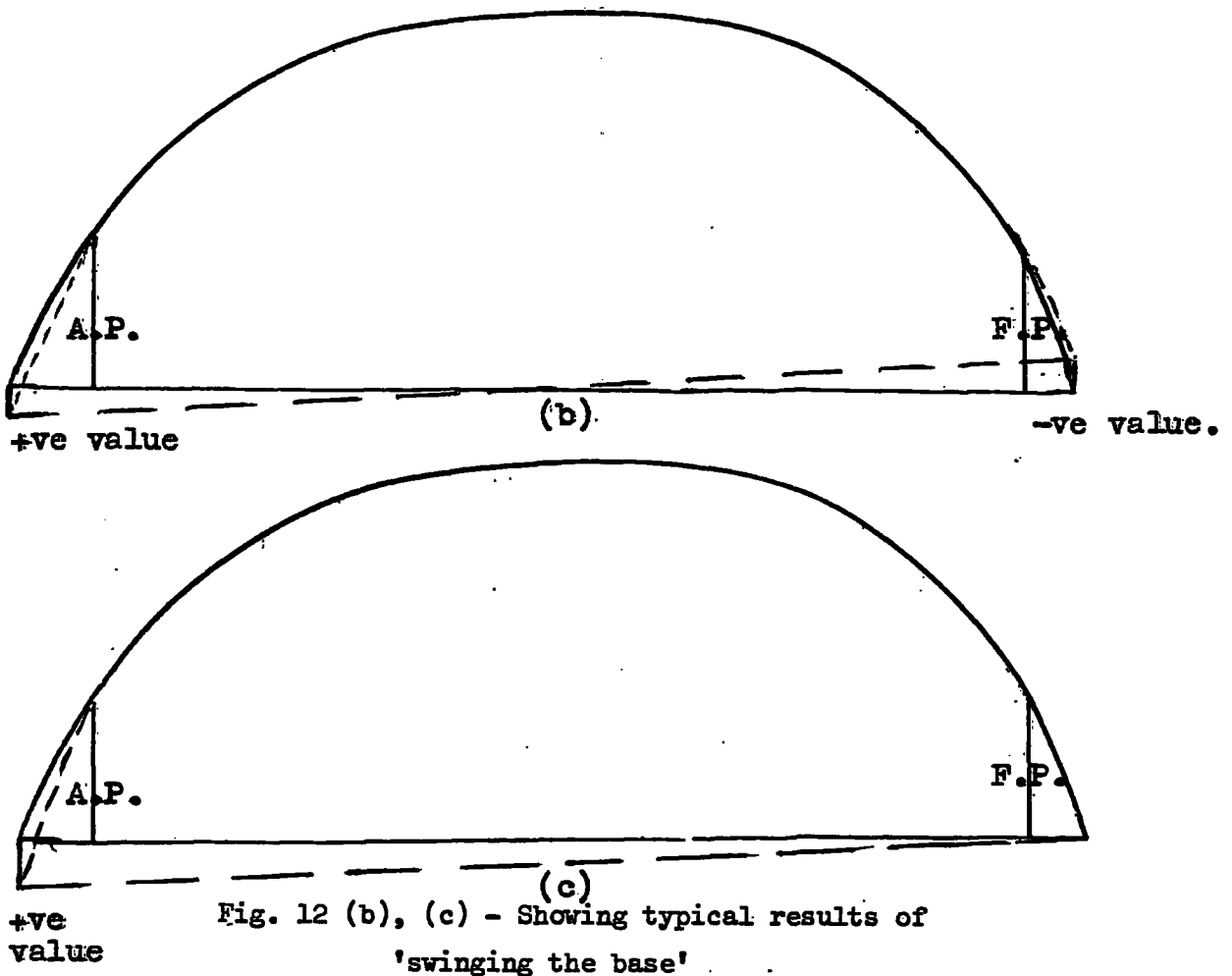


Fig. 12 (b), (c) - Showing typical results of  
'swinging the base'

Further, it causes the greatest change in those ordinate values towards the ends, see fig. 12b (or at the least, in the ordinates towards one end, see fig. 12c), when in fact it would seem more reasonable to make the bulk of the change in those ordinates which contribute most to the total reading, namely the ordinates towards the centre.

Since the resultant ordinate values for Lloyd's curve are determined for the continuous material weight provided, the curve



is correct for weight. But the shape of the basic weight curve in the first place is dependent upon the coefficients "a", coefficients which are derived using the assumption that certain standard relationships exist between block coefficient and the extent and position of the parallel mid-body. These relationships may be departed from in any given design, and it is logical to deduce that the L.C.G. derived from the continuous weight distribution curve will not, in general, be the same as that calculated by the programme using the addition and subtraction of moments in the usual way, and using the L.C.G. for the TOTAL weight distribution as given by the builder. An incorrect L.C.G. is the only measure to be corrected, therefore, as far as the distribution of the continuous material is concerned.

The above method of 'swinging the base' at this stage was, therefore, discarded in favour of a method of tilting (or displacing) the ordinates. By this method end ordinates remain of zero value, the weight under the curve is unaffected, (See page 47), and those ordinates which contribute most to the calculation of the L.C.G. (the larger, more central ordinates) are displaced most. Ordinates are, therefore, swung about their base line in the following manner:

From the curve, the vertical and horizontal measures of the centroid are computed. Let the position of the calculated centroid be  $G_1$ , and the known true position, for the continuous weight be

G. The horizontal movement required of the L.C.G. is, therefore,  $GG_1$  ft. Let  $H$  be the vertical measure of  $G_1$  from the base line of the curve. (Units for  $H$  are ton/ft) Let the ratio  $GG_1/H$  be called  $M$ , with units  $\text{ft}^2/\text{ton}$ .

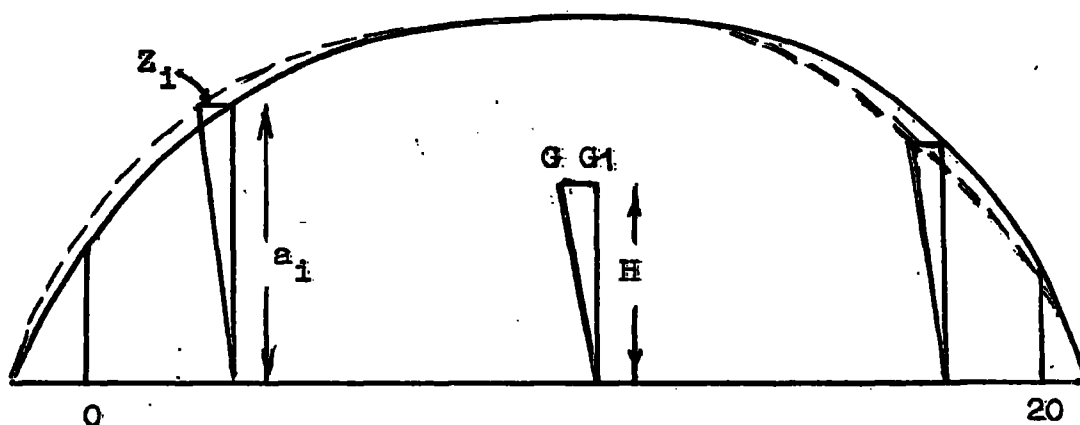


Fig. 13.

Multiplication of each ordinate of the curve by this ratio (in the same manner as a tangent ratio) gives the distance in feet, through which each ordinate respectively has to be moved horizontally. In the case of ordinate  $\underline{i}$ , whose value is  $a_i$  ton/ft.,

we have:

$$a_i \text{ ton/ft.} \times M^{\text{ft}^2} / \text{ton} = (\text{say}) z_i \text{ ft.}$$

where  $z_i$  is the horizontal shift required of  $a_i$ , in order that recalculation of the weight gives the same value as before, but now provides the correct L.C.G. position. (See fig. 13)

It can be seen from the following diagrams (fig. 14) that the "pushing over" of the weight curve does not alter the weight represented. Consider any element of area PQ.

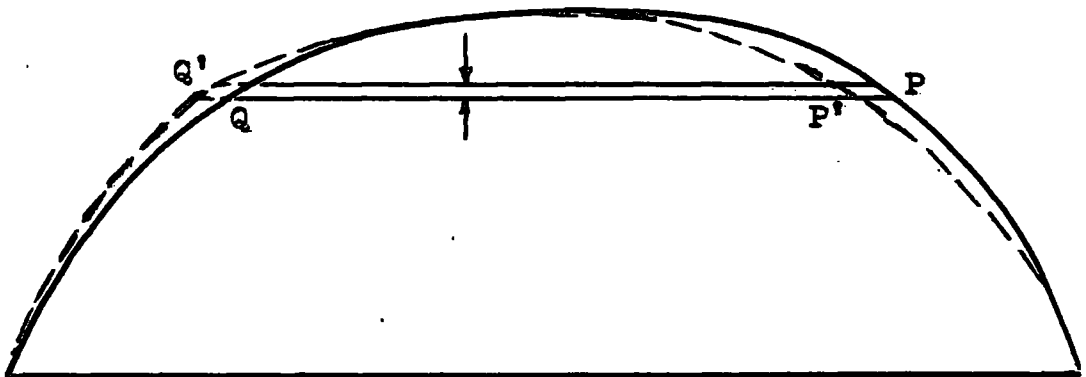


Fig. 14.

Since all points of the element are equidistant from the base line, the distance  $PP'$  must equal the distance  $QQ'$ , and the distances  $PQ$  and  $P'Q'$  are equal. The area of the strip is, therefore, unchanged. Similarly for all strips.

An alternative method is to consider the element  $ABCD$  of fig. 15 - (a) triangular end and (b) any portion between the perpendiculars. The ordinates are sufficiently close to assume  $CB$  is a straight line fig. 15 (b); in fig. 15 (a)  $B$  and  $C$  are coincident.

Fig. 15 (a).

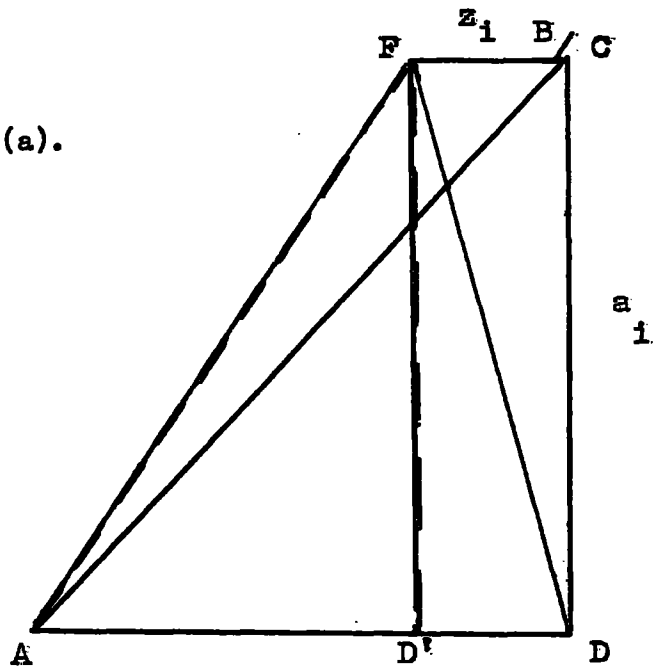
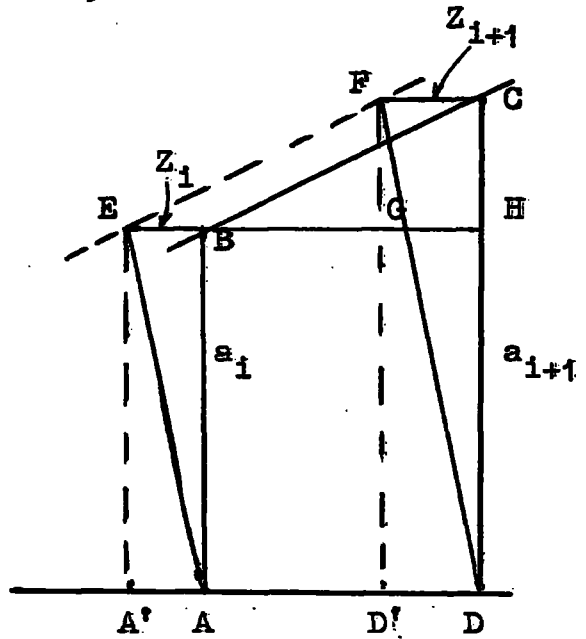


Fig. 15 (b)



Treating  $M$  in the same way as a tangent ratio, we have e.g.  $a_5 \times M = z_5$ , and  $a_6 \times M = z_6$ . In (b),  $E$  and  $F$  are the points on the new curve corresponding to  $B$  and  $C$ . Area  $EGDA$  equals area  $BHDA$  (since  $EG = BH = AD$ ; parallel lines  $AE$ ,  $DG$  and  $AB$ ,  $DH$ ). Also triangles  $BHC$  and  $EGF$  are equal. Therefore the new area equals the old area. Similarly for an end triangle as in (a). Considering the whole ordinate as moving across, we now have the new ordinate positions at  $A'$  and  $D'$  in (b), and at  $D'$  in (a).

At this stage in the programme the interpolation routine is entered to obtain ordinate values at every one-hundredth of the ship length over-all. Again ordinates are summed in pairs progressively throughout the whole length and the averages projected forward from the rearmost ordinate of each division.

Reference to fig. 16 will make it clear that the horizontal movements  $z_i$  of the ordinates of the curve cause the L.C.G. to be moved to the correct position.

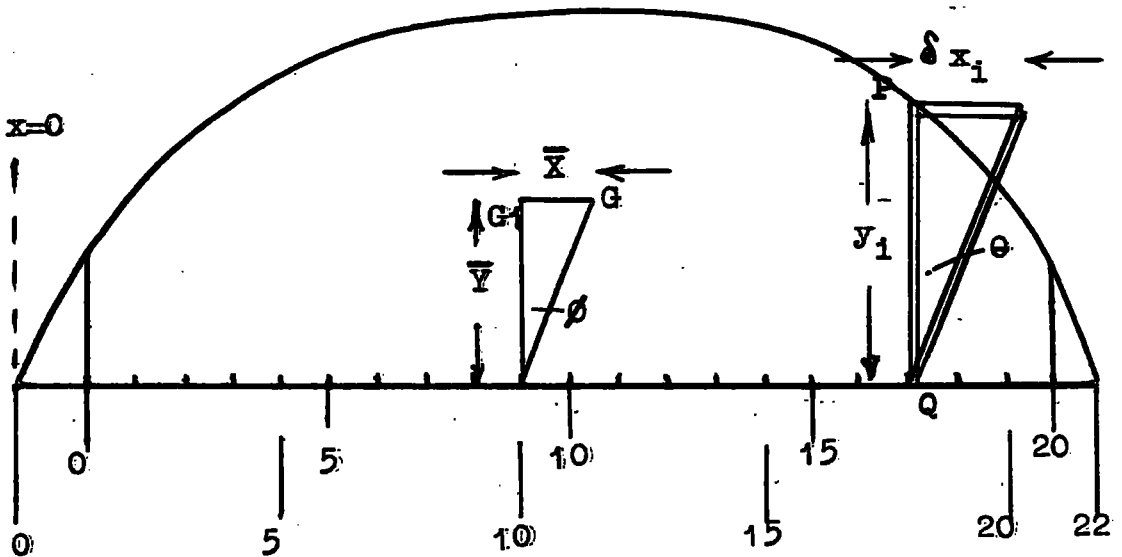


Fig. 16. (i) Showing Lloyd's Station Numbers (upper) and the corresponding Programme Station Numbers (lower).

(ii) Indicating movement of L.C.G.

Let PQ be an element of area  $a_i$  and height  $y_i$ , and let it be tilted through angle  $\theta$  about the base line.

The increase of moment about  $x = 0$  is  $a_i \frac{\delta x_i}{2}$ , and the sum of all such moments is  $\sum a_i \frac{\delta x_i}{2} = \sum a_i \frac{y_i}{2} \tan \theta = \tan \theta A y$ .

Also increase in moment of total area

$$= A\bar{X} = A \bar{y} \tan\phi$$

$$\therefore \theta = \phi$$

The graph on page 53 shows the initial points on the continuous weight distribution curve (shown as triangles), the displaced position as determined by the above theory (shown as squares), and the final smooth curve drawn through the points obtained through the interpolation routine.

Page 54 shows the relevant input data for A.842 using Lloyd's method for the distribution of the Continuous Material, and on page 55 may be seen the tabulated values for this distribution. Page 56 shows the corresponding graph output.

\* \* \* \* \*

Since we are concerned with obtaining values every one-hundredth of the overall actual, or estimated, length, it is better to consider such lengths throughout. When the interpolation routine is entered, 23 values of  $X_i$  and  $Y_i$  (actually  $X_i$  and  $A_i$ ) are used from store, in order to determine the 101 equally spaced ordinates (including two end ordinates in each case, whose values are 0, 0). Lloyd's 'a' values are renumbered for this purpose as illustrated in fig. 16. The distance  $X_0 X_{11}$  is the actual, or estimated, length of the overhang of the stern.

Similarly, the distance  $X_{21} X_{22}$  is the actual, or estimated, length of the bow overhang.

The interpolation routine entered is a three point Lagrange method, which is also used for the Buoyancy Section.

101 ordinates are determined for abscissae at regular intervals along the ship length. For the first three points input,  $x_0, x_1, x_2$ , ordinates are determined for those abscissae, if any, which lie in the first portion,  $x_0 - x_1$ . If the abscissae lie in the second portion,  $x_1 - x_2$ , the first value input is dropped, and a fourth value is picked up,  $x_3$ . The three points used are now  $x_1, x_2, x_3$  (which are renamed  $x_0, x_1, x_2$  in the programme) and the ordinates required have abscissae lying in the new range  $x_0 - x_1$ , i.e. the leading portion. Each time a new input ordinate is adopted the new set become  $x_0, x_1, x_2$ .

This process is repeated until ordinate number 50 is reached, then the process is changed slightly to find ordinates in the second portion of each set. This ensures that ordinates are found up to the extreme fore end.

\* \* \* \* \*

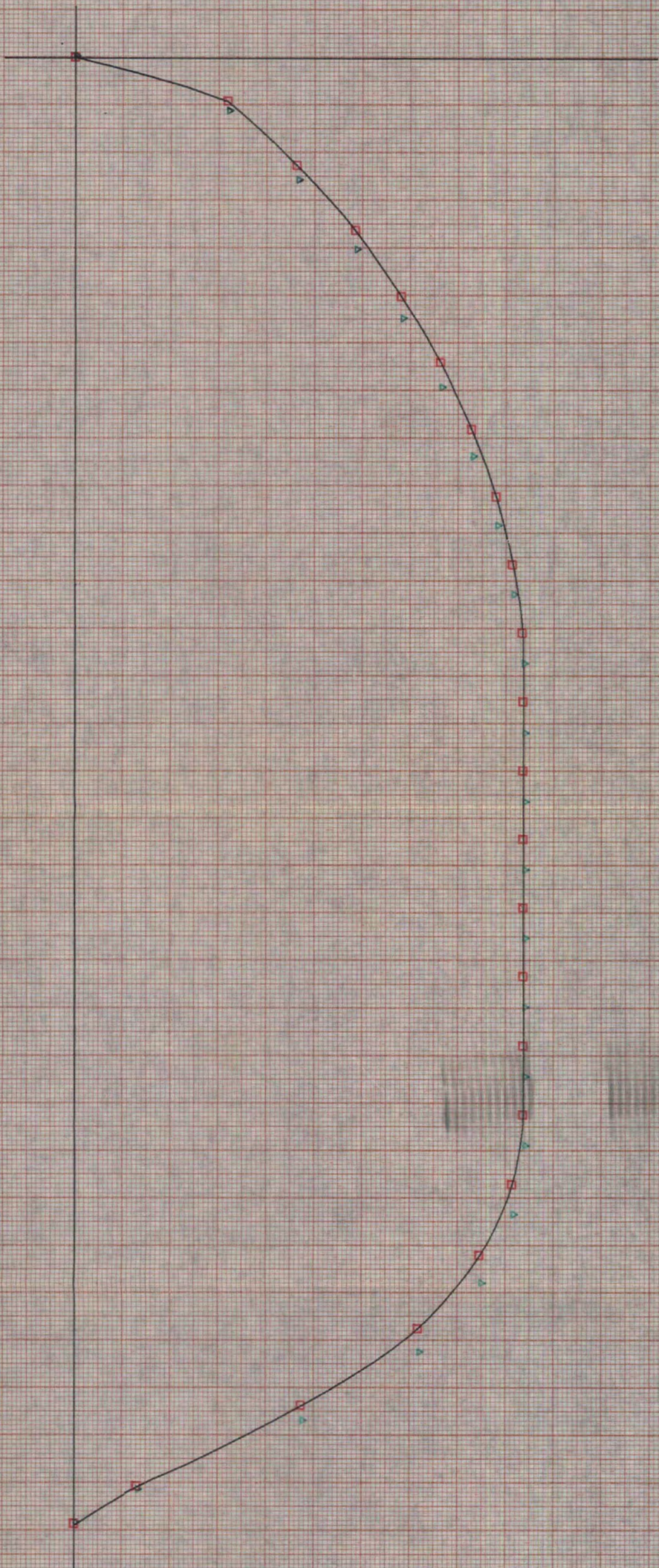
A comparison of graph output for A.842 using both Biles Coffin method and Lloyd's method is shown on page 62 ; Biles Coffin curve is in red and Lloyd's curve in green. Reference will be made to this again in the Bending Moment Section, and in the Load Curve and Shear Force Curve Sections which lead up to it.



CONTINUOUS WEIGHT CURVE, (LLOYD'S METHOD)

ORIGINAL POSITION - TRIANGLES.

ADJUSTED POSITION - SQUARES.





Tape 2 (Contd). (This part of Tape 2 not required after the first data run).

If Continuous Weight is to be distributed by Biles Coffin method, complete lines (a), (b), (c), (d) below, otherwise complete (e) from Lloyds tables SR 64/15.

For FIRST data run only:

Programme  
Variable.

(a) Weight of Overhang of Stern.	W33
(b) Weight of Overhang of Bow.	W34
(c) L.C.G. of Overhang of Stern, from Stern.	L4
(d) L.C.G. of Overhang of Bow, from Stern.	L5

(e) For FIRST data run only:

	Stn. 0	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6
0	0.340	0.495	0.625	0.727	0.815	0.884	0.940
Stn. 7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Stn.13	Stn.14
0.976	0.998	1.000	1.000	1.000	1.000	1.000	1.000
Stn.15	Stn.16	Stn.17	Stn.18	Stn.19	Stn.20		
1.000	0.975	0.903	0.766	0.505	0.140	0	

SHIPYARD A.

SHIP NO. 842

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

(LLOYD'S DISTRIBUTION)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.63	1	1.79	2	2.75	3	3.36
4	3.71	5	4.04	6	4.36	7	4.67
8	4.97	9	5.25	10	5.52	11	5.78
12	6.02	13	6.25	14	6.47	15	6.68
16	6.88	17	7.06	18	7.24	19	7.42
20	7.58	21	7.74	22	7.89	23	8.04
24	8.17	25	8.31	26	8.43	27	8.55
28	8.66	29	8.76	30	8.85	31	8.92
32	8.99	33	9.06	34	9.12	35	9.18
36	9.24	37	9.28	38	9.32	39	9.34
40	9.35	41	9.35	42	9.36	43	9.36
44	9.36	45	9.36	46	9.36	47	9.36
48	9.36	49	9.36	50	9.36	51	9.36
52	9.36	53	9.36	54	9.36	55	9.36
56	9.36	57	9.36	58	9.36	59	9.36
60	9.36	61	9.36	62	9.36	63	9.36
64	9.36	65	9.36	66	9.36	67	9.36
68	9.36	69	9.36	70	9.36	71	9.36
72	9.35	73	9.31	74	9.27	75	9.21
76	9.15	77	9.06	78	8.94	79	8.81
80	8.67	81	8.50	82	8.30	83	8.07
84	7.81	85	7.52	86	7.21	87	6.85
88	6.44	89	5.99	90	5.50	91	4.97
92	4.42	93	3.84	94	3.24	95	2.61
96	1.95	97	1.31	98	0.75	99	0.24
100	0.00						

Table 8.

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 0.5  
-----

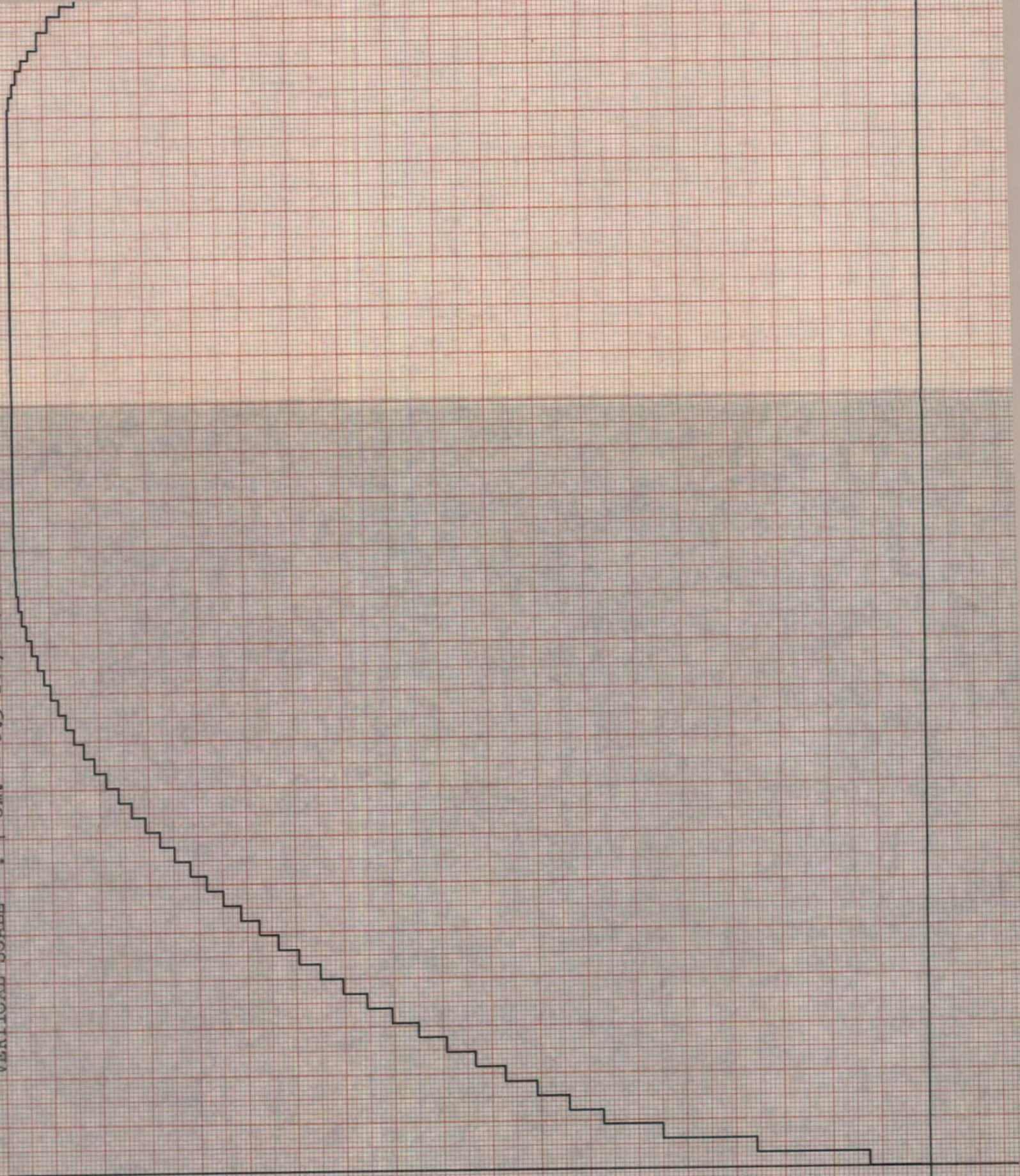


CONTINUOUS WEIGHT ORDINATES (PROJECTED FORWARD)

(Lloyd's)

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 0.5 TON/FT.





As mentioned on page (v) of the introduction, and remembering that the programme is to cater for the builder in the initial design stages, when end values may not be decided upon, Lloyd's suggest that the areas aft of their Station No. 0 and forward of Station No. 20 may be taken as  $0.01133 \times m \times L_{BP}$ , and  $0.00175 \times m \times L_{BP}$  respectively, i.e. a total end area of  $0.01308 \times m \times L_{BP}$ .

Again, Lloyd's indicate that the overhangs of stern and bow may be taken as  $0.05 \times L_{BP}$  and  $0.025 \times L_{BP}$  respectively. The end areas calculated on these latter measures would be:-

$$\begin{aligned} \text{Stern} & \quad \frac{1}{2} \times 0.05 \times L_{BP} \times a_0. \\ \text{Bow} & \quad \frac{1}{2} \times 0.025 \times L_{BP} \times a_{20}. \end{aligned}$$

However, if we take the true lengths of the overhangs, if known we have the end areas equal to:-

$$\begin{aligned} \text{Stern} & \quad \frac{1}{2} \times L_1 \times a_0. \\ \text{Bow} & \quad \frac{1}{2} \times L_2 \times a_{20}. \end{aligned}$$

The effect on 'm' using these various values was investigated.

The following table of values has been drawn up, using these various formulae, for a number of different ships from four different shipyards on the River Wear. It will be noticed that the differences are of the order 0.04 to 0.05 ton/ft. for cont. wts. of 4000-5000 tons.

1. YARD A.

SHIP NO.	"M" Values as calculated from:-		
	$0.01308 \times L_{BP}$ (Lloyds Areas)	$\frac{1}{2} \left( \begin{matrix} 0.025 \times L_{BP} \times a_{20} \\ + \\ 0.05 \times L_{BP} \times a_0 \end{matrix} \right)$ (Lloyds ends)	$\frac{1}{2} \left( \begin{matrix} L_1 \times a_0 \\ + \\ L_2 \times a_{20} \end{matrix} \right)$ (Actual or estimated ends)
842	9.31	9.34	9.36
844	8.49	8.51	8.54
849	7.67	7.70	7.71
850	8.01	8.03	8.05
SD.14	6.94	6.97	7.00

2. YARD B.

408	7.19	7.22	7.24
409	7.61	7.64	7.67

3. YARD C.

721	15.11	15.16	15.21
-----	-------	-------	-------

4. YARD D.

873	7.29	7.32	7.33
837	4.81	4.83	4.85
843	6.29	6.31	6.31
849	6.14	6.16	6.16
850	6.17	6.19	6.19
889	5.52	5.54	5.54

Using  $0.01133 \times L_{BP} \times m$  as the weight of overhang of stern, and  $0.00175 \times L_{BP} \times m$  as that of the bow section, and since Lloyd's measures  $a_0$  and  $a_{20}$  are fixed, we can find the equivalent lengths of stern and bow from the two triangular ends. Calling the lengths  $X_1$  and  $X_2$  respectively we have, for ship No. A.842.

$$\text{Stern: } \frac{X_1 \times a_0 \times m}{2} = 0.01133 \times L_{BP} \times m$$

$$X_1 = \frac{0.02266 \times L_{BP}}{a_0} \text{ where } L_{BP} = 580 \text{ ft.}, \text{ and } a_0 = 0.34.$$

$$X_1 = \frac{0.02266 \times 580}{0.34} = \underline{38.66 \text{ ft.}}$$

In fact, the length  $X_1$  is 23 ft.

$$\text{Bow: } \frac{X_2 \times a_{20} \times m}{2} = 0.00175 \times L_{BP} \times m$$

$$X_2 = \frac{0.00175 \times 580 \times 2}{0.14} = \underline{14.5 \text{ ft.}}$$

In fact,  $X_2$  is 14 ft.



Again, taking Lloyd's suggestion for the length of the overhangs as  $0.05 \times L_{BP}$ , and  $0.025 \times L_{BP}$  for the stern and bow, we have a stern overhang of 29 ft., and a bow overhang of 14.5 ft., against actual length of 23 ft. and 14 ft.

A check on the results for a number of ships, using these measures showed possible wide discrepancies in implied lengths of sterns (see Table 10). It was decided, therefore, not to use the recommended values, but to use estimated values (which are quite likely to be very near the actual final value). It was felt that such estimations would be much nearer the mark in each individual case and give a distribution more in line with that of the final plans. The last column in table 10 indicates the expected or estimated lengths, which in these instances are also the final actual lengths.

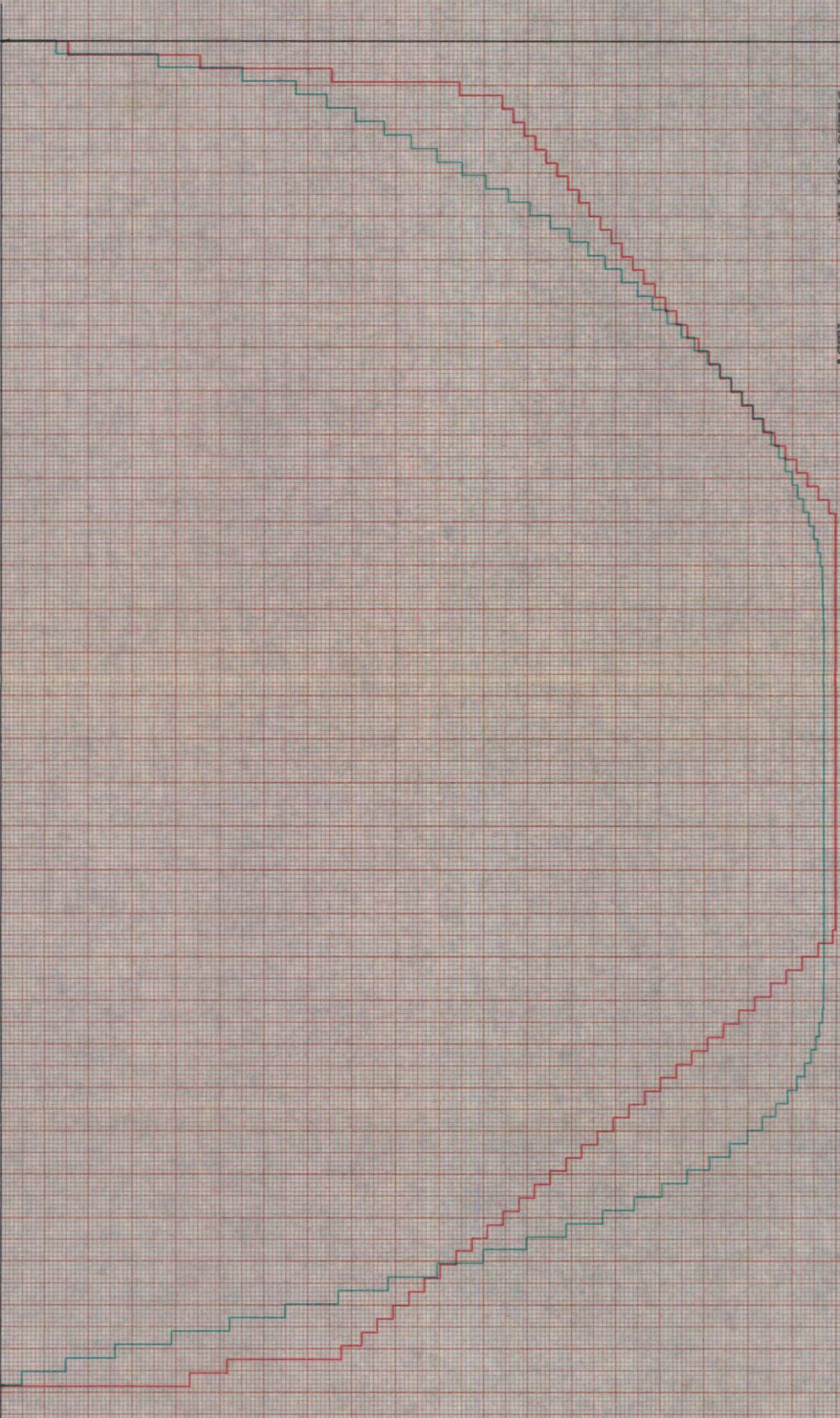
Implied Stern and Bow Overhangs calculated from:-						
Ship	End Areas		End Lengths		Actual (or estimated) Lengths	
	<u>Stern</u>	<u>Bow</u>	<u>Stern</u>	<u>Bow</u>	<u>Stern</u>	<u>Bow</u>
A.842	38.655	14.50	29.00	14.500	23.00	14.00
A.844	38.655	14.50	29.00	14.500	23.00	7.00
A.849	37.322	14.00	28.00	14.000	22.00	13.00
A.850	36.656	13.75	27.50	13.750	22.00	11.00
SD.14	29.325	11.00	22.00	11.000	12.50	10.00
B.408	30.324	11.375	22.750	11.375	15.85	13.3
B.409	32.257	12.100	24.200	12.100	16.73	6.00
C.721	50.652	18.865	38.00	19.000	27.36	10.58
D.873	28.743	10.827	21.500	10.750	18.25	8.25
D.837	27.992	10.500	21.000	10.500	13.00	7.04
D.843	33.324	12.500	25.000	12.500	21.59	17.77
D.849	32.657	12.250	24.500	12.250	21.00	21.01
D.850	31.991	12.000	24.000	12.000	22.79	15.57
D.889	29.991	11.250	22.500	11.250	20.42	16.58



CONTINUOUS WEIGHT DISTRIBUTIONS.

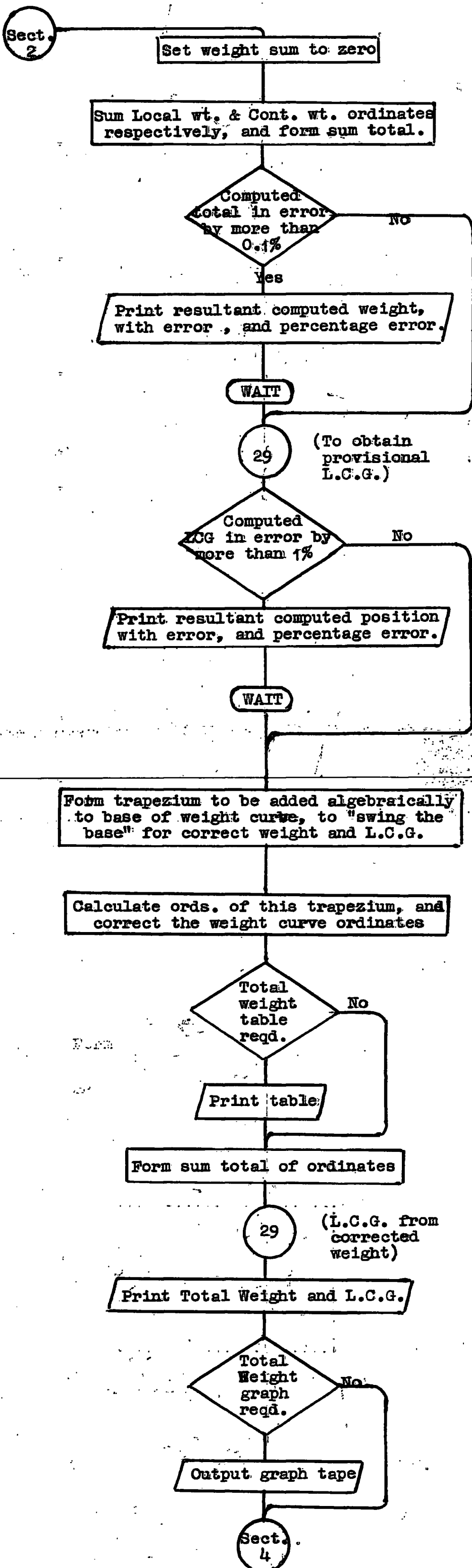
LLOYD'S METHOD - GREEN.

BILES CORFIN - RED.





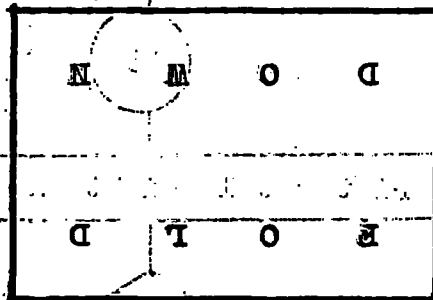
TOTAL WEIGHT SECTION (3)



FLOW CHART

(Section 3).

TOTAL WEIGHT SECTION.



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### PART 3

#### LOCAL WEIGHTS AND CONTINUOUS WEIGHT

#### COMBINED RESULTS

Ordinate values from the previous two parts of the programme (YR - local weights: VR - continuous weight) are now respectively summed in order, to produce Total Weight Curve ordinates, for all ordinates 0 - 99. (F. Pt. variables YR are used again for these summed ordinates). Calculation of total weight under this curve (which is computed as the product of the sum of the ordinates and their distance apart) yields a result which may differ slightly from the real displacement. Calculation of the longitudinal L.C.G. may differ very slightly from the actual value read in, especially if Biles Coffin method has been used. Before these Total Weight Curve ordinates are printed out, therefore, they are amended to ensure the correct positioning of the L.C.G., and to give a correct (or very nearly so) displacement. This is done by 'Swinging the Base'. If the weight value before swinging is in error by more than 0.1% it is output and the programme WAITS. A similar indication is made if the L.C.G. is out by 1%. The programme may be continued if so desired.

#### Swinging the Base

As mentioned above, the weight ordinates are summed and multiplied by the common interval (L6). This computes the total weight under the curve.

The longitudinal moment of weight about the stern is found by multiplying each ordinate in turn by its (forward) common interval (L6) and again by the distance from the stern to the centre of that common interval, and summing. These computed figures must be corrected, and this is done by raising or lowering, and tilting the base of the weight curve. This combined movement of the base line adjusts the weight (for each ordinate) and also adjusts the position of the L.C.G.

See below for method and formulae applied.

We now have in store the original weight ordinates and the corrections to be applied. These are respectively summed algebraically to obtain the corrected weight curve ordinates which are now printed out under the title:-

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

Ord.	Weight	Ord.	Weight	Ord.	Weight	Ord.	Weight
No.	ton/ft.	No.	ton/ft.	No.	ton/ft.	No.	ton/ft.

See page 72 for the complete table of results.

After the 100 ordinate values are printed they are again summed (using F.Pt. variable S again) and their moments about the stern again calculated. From these two, the position of the L.C.G. is determined by division, and printed out together with the total weight. This allows checking with the read-in values of weight and L.C.G.

Method Used

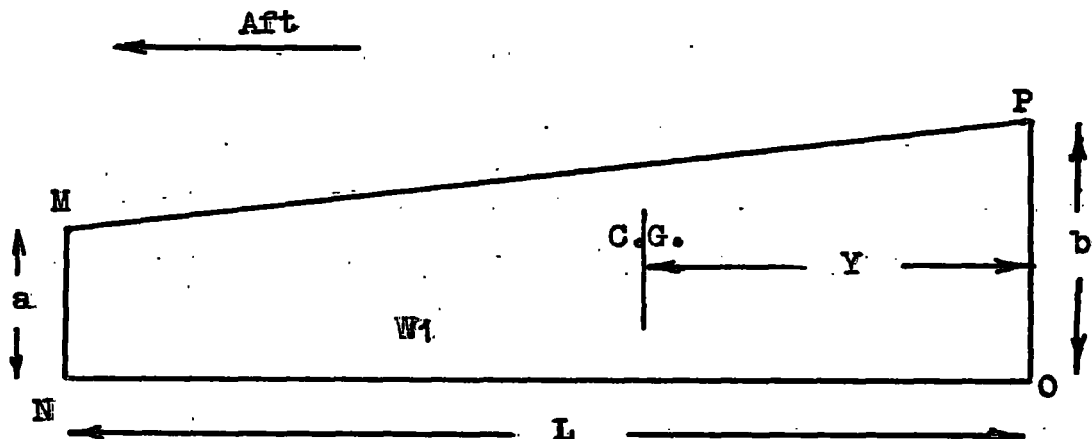


Fig. 18.

W1 is the difference between the true and the computed weights.

(W1 in these notes is programmed as W32).

i.e. MNOP is the trapezium to be added (algebraically) to the base of



the original weight curve. a and b are found using the formulae:-

$$a = \frac{Wl}{L^2} (6Y - 2L). \quad b = \frac{2(Wl)}{L} - a.$$

where a is the smaller end.

Note: Y is always measured from the larger end, and therefore always less than L/2. In any given case, a may equal b. The programme provides for the aft ordinate of the trapezium to be called D and the forward end A in all cases, the difference giving a positive or negative slope as the case may be.

Each condition with its resultant corrective effect is listed below, where S is the computed weight and Wl is the correction to be added. (i.e.  $W = Wl + S$ ).

In all cases, values of DR obtained below are averaged for each pair of readings in turn, since values on the weight curve, etc., are projected forward.

Case I Wl positive. Both D and A positive. Also (D-A) positive.

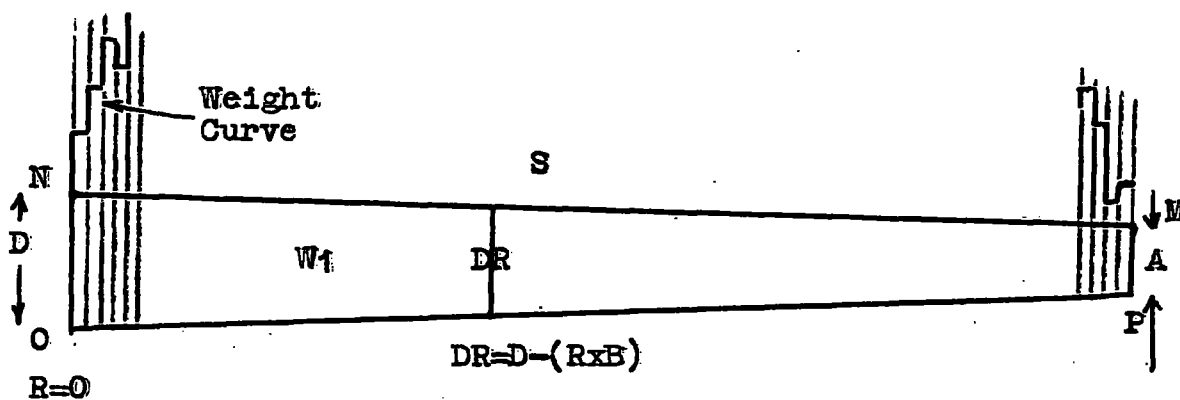
$B = D - A$ . (These are also the F.Pt. variables used).

$B = B/100$  (B is now the step per division length - L6).

Fig. 19 shows (D - A) positive. i.e. + ve slope for side OP. Any ordinate DR is now given by

$DR = D - (R \times B)$  where R takes all values 0 to 99 in turn.

DR decreases with increasing R.  $D_{100} = A$ .



LCG moves aft; weight increases, since  $W_1$  +ve.

Fig. 19.

In fig. (19), fig. (20), etc.,  $S$  is the computed sum of weights and the trapezium MNOP represents the weight  $W_1$  to be 'added'.

Case II  $W_1$  positive. Both  $D$  and  $A$  positive. But  $(D - A)$  negative.

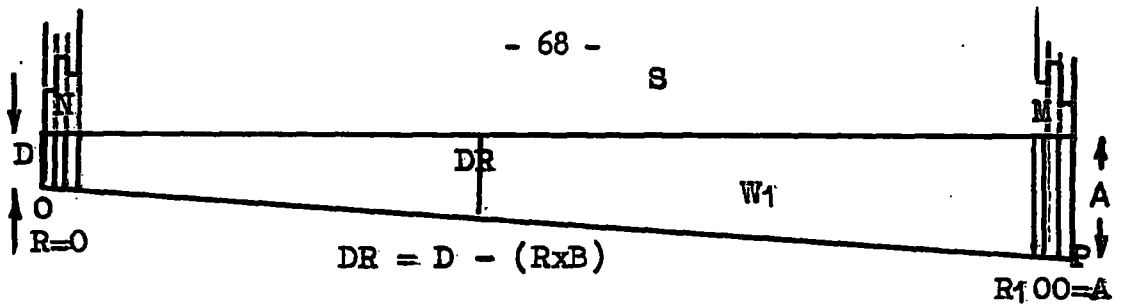
$B$  is again the step per division length -  $L/6$ .

Fig. (20) shows  $(D - A)$  negative. i.e. -ve slope for side  $OP$ .

Any ordinate is now given by

$$DR = D - (R \times B),$$

where  $B$  is -ve., so that  $DR$  increases with increasing  $R$ .



L.C.G. moves forward; weight increases since  $W1 +ve$ .

Fig. 20.

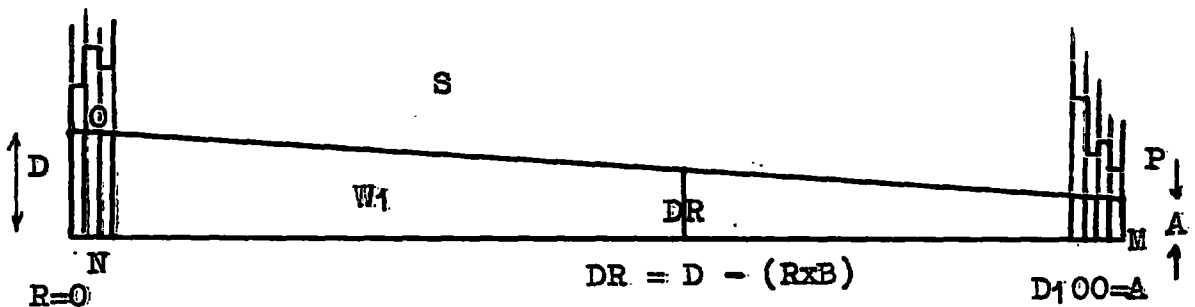
Case III  $W1$  negative. Both  $\underline{D}$  and  $\underline{A}$  negative. Also  $(D - A) -ve$ .

$B$  (i.e. step division) negative. Fig. (21) shows this.

Any ordinate is now given by

$$DR = D - (R \times B),$$

where  $B$  is  $-ve$ , so that  $DR$  is decreasing numerically (or becoming less negative) with increasing  $R$ .



L.C.G. moves forward; weight decreases since  $W1 -ve$ .

Fig. 21.

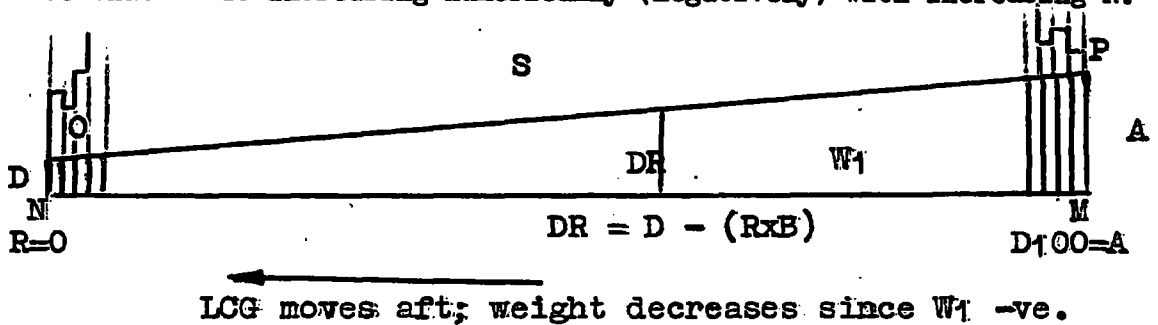
Case IV W1 negative. Both D and A negative. But (D - A) positive.

B is now positive. Fig. (22):

Any ordinate is now given by

$$DR = D - (R \times B),$$

so that DR is increasing numerically (negatively) with increasing R.



**Fig. 22.**

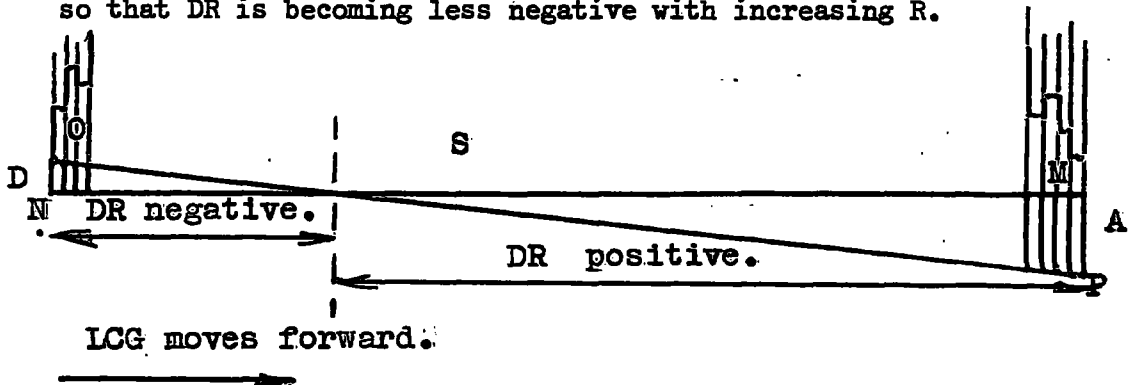
Case V      D computed negative)  
                 A computed positive)     $A = -D$  if  $W_1 = 0$ .

(D - A) negative in this case. OP has -ve slope; i.e. B -ve.

Any ordinate DR is given by

$$DR = D - (R \times B),$$

so that DR is becoming less negative with increasing R.



**Fig. 23.**

- (i) Weight unchanged if  $A = -D$ .
- (ii) If  $W_1$  -ve, then  $|D|$  gr  $|A|$ .
- (iii) If  $W_1$  positive, then  $|D|$  less than  $|A|$ .

Case VI      D computed positive)  
                   A computed negative)  $A = -D$  if  $W_1 = 0$ .

( $D - A$ ) positive in this case. OP has positive slope. i.e. B +ve.

Any ordinate DR is given by

$$DR = D - (R \times B),$$

so that DR decreases with increasing R.

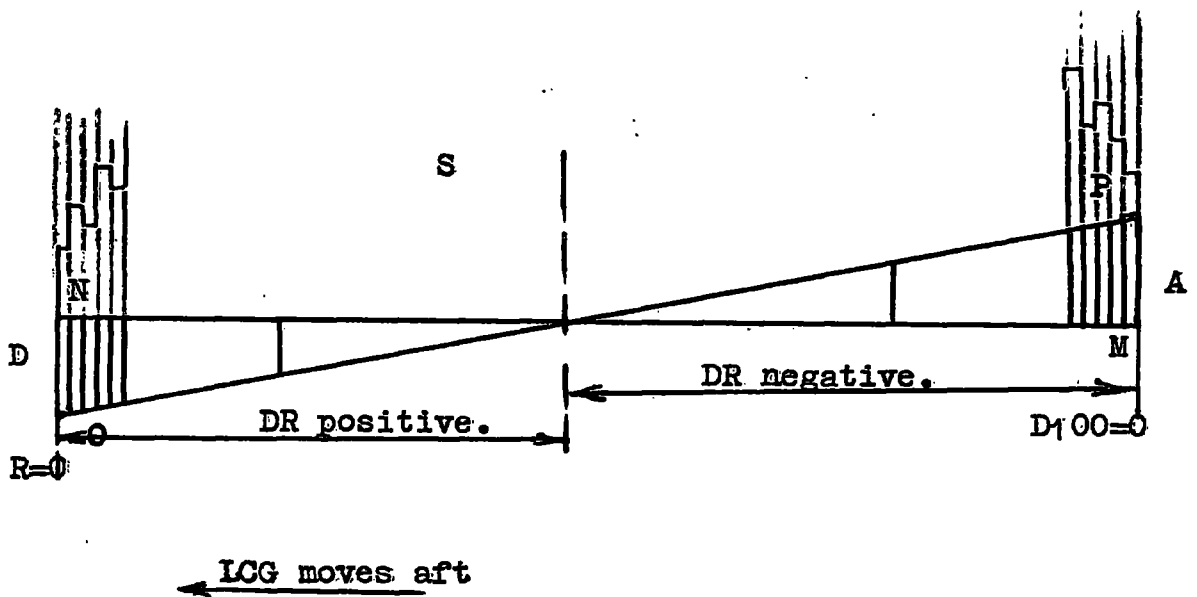


Fig. 24.

- (i) Weight unchanged if  $A = -D$ .
- (ii) If  $W_1$  negative, then  $|A|$  gr  $|D|$ .
- (iii) If  $W_1$  positive, then  $|A|$  less than  $|D|$ .

Note: In cases (v) and (vi), if the computed weight and the actual weight are the same, but the L.C.G. is incorrect, then A and D are equal in magnitude, but opposite in sign.

Page 72 shows the tabulated results for A842 (using Lloyd's method for the distribution of the Continuous material), and page 73 contains the corresponding graph output, in green.

Superimposed on page 73 is the graph output using Biles Coffin method for the Continuous Weight. This graph is shown in red, and the corresponding table is on page 72(a).

RESULTANT COMPUTED TOTAL WEIGHT = 21358.56 TONS  
 ERROR = 39.91 TONS % ERROR = 0.19

[illegible]

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)  
(BILES COFFIN DISTRIBUTION)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.78	1	2.18	2	4.16	3	8.52
4	18.85	5	29.07	6	34.84	7	13.74
8	16.71	9	18.88	10	20.93	11	18.51
12	18.53	13	29.29	14	36.48	15	36.08
16	34.69	17	34.85	18	24.85	19	22.35
20	27.41	21	19.89	22	20.88	23	21.20
24	20.80	25	21.32	26	21.85	27	22.37
28	22.61	29	23.77	30	35.31	31	26.05
32	25.12	33	26.00	34	26.40	35	26.73
36	26.97	37	27.21	38	27.33	39	27.24
40	27.48	41	118.69	42	121.53	43	120.99
44	120.02	45	131.38	46	38.87	47	30.39
48	29.63	49	30.03	50	30.09	51	30.15
52	30.22	53	30.28	54	30.11	55	29.91
56	37.44	57	29.47	58	29.68	59	29.98
60	29.99	61	30.00	62	30.02	63	30.03
64	29.79	65	30.29	66	33.74	67	125.27
68	121.14	69	120.93	70	120.19	71	130.76
72	30.64	73	30.01	74	29.25	75	28.49
76	28.54	77	27.95	78	27.32	79	26.70
80	26.07	81	27.07	82	35.53	83	24.04
84	22.77	85	21.90	86	21.04	87	20.17
88	19.31	89	18.32	90	12.71	91	12.07
92	24.65	93	39.58	94	25.35	95	19.80
96	14.00	97	7.04	98	3.19	99	2.48

WEIGHT

L.C.G. FWD. A.E.

21318.65

321.79

Table 11(a).

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

(LLOYD'S DISTRIBUTION)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
0	0.69	1	2.01	2	3.72	3	7.48
4	17.72	5	28.12	6	34.06	7	13.12
8	16.24	9	18.54	10	20.71	11	18.39
12	18.51	13	29.35	14	36.60	15	36.26
16	34.91	17	35.11	18	25.15	19	22.67
20	27.74	21	20.22	22	21.21	23	21.53
24	21.11	25	21.62	26	22.12	27	22.61
28	22.80	29	23.92	30	35.39	31	26.06
32	25.05	33	25.84	34	26.15	35	26.46
36	26.76	37	27.05	38	27.21	39	27.14
40	27.39	41	118.61	42	121.45	43	120.92
44	119.95	45	131.32	46	38.81	47	30.34
48	29.58	49	29.98	50	30.05	51	30.11
52	30.18	53	30.24	54	30.08	55	29.88
56	37.41	57	29.45	58	29.67	59	29.97
60	29.98	61	30.00	62	30.01	63	30.03
64	29.80	65	30.29	66	33.78	67	125.45
68	121.47	69	121.41	70	120.82	71	131.54
72	31.56	73	31.05	74	30.40	75	29.73
76	29.87	77	29.34	78	28.75	79	28.14
80	27.51	81	28.50	82	36.91	83	25.34
84	23.96	85	22.96	86	21.93	87	20.86
88	19.73	89	18.44	90	12.50	91	11.48
92	23.66	93	38.16	94	23.49	95	17.46
96	11.15	97	3.77	98	0.96	99	0.29

WEIGHT	L.C.G. FWD. A/E.
21318.65	321.79

Table 11.



TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0  
-----



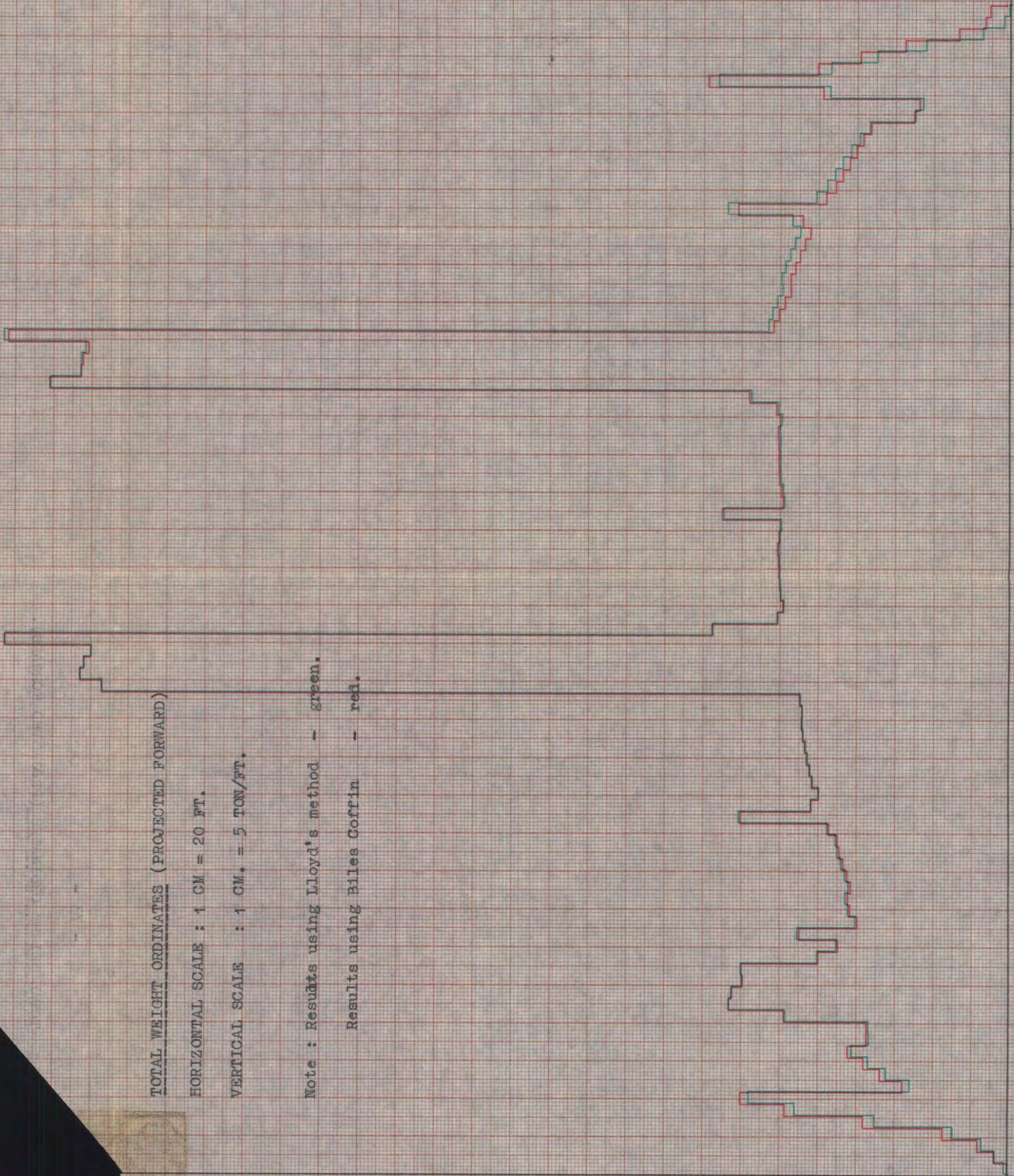
TOTAL WEIGHT ORDINATES (PROJECTED FORWARD)

HORIZONTAL SCALE : 1 CM = 20 FT.

VERTICAL SCALE : 1 CM. = 5 TON/FT.

Note : Results using Lloyd's method - green.

Results using Biles Coffin - red.



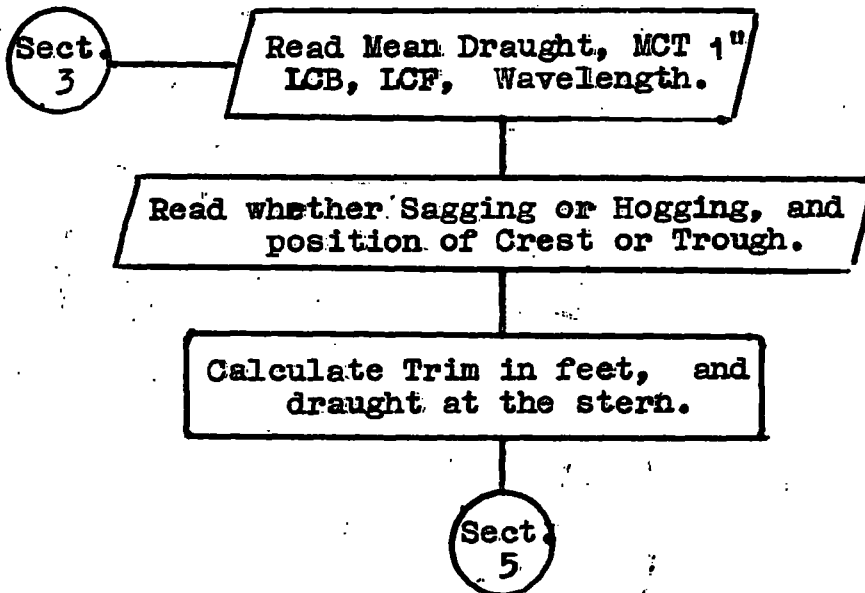




(Section 4).

COMPUTATION OF TRIM, AND DRAUGHT AT  
STERN.

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PART 4

COMPUTATION OF TRIM AND DRAUGHT AT STERN

Computing Trim

(Note: the vessel trims about its L.C.F. at the draught considered). Consider the situation where the L.C.G. and L.C.B. are not coincident. There will be a moment tending to tilt (known as trimming) the ship lengthwise about the L.C.F. Fig. 25. Let the distance between the L.C.G. and L.C.B. be  $d$ , and let the displacement of the vessel be  $\Delta$ . Then the moment above will be  $\Delta.d$ . This will trim the ship until the two centres are coincident, and there will be some measure (in inches) by which the vessel at the after-perpendicular is more (or less) submerged than at the fore-perpendicular. Fig. 26. This is known as the trim in inches. Now the moment to change this trim by 1 inch is known as the MCT 1". Dividing the above moment by  $12 \times \text{MCT } 1''$  we obtain the trim in feet over the  $L_{BP}$ .

$$\text{i.e. Trim (in feet)} = \frac{\Delta.d}{12 \times \text{MCT } 1''}$$

Further division by  $L_{BP}$  gives the trim in ft. per foot, and since it trims about the L.C.F. we find:

$$\text{Draught at stern} = \text{Mean Draught} + \frac{(\text{Trim} \times \text{L.C.F. fwd. of A.E})}{\text{Length}_{BP}}$$

The draught at any position along the length of the vessel is easily

determined from its distance from the stern, in conjunction with the trim per ft.

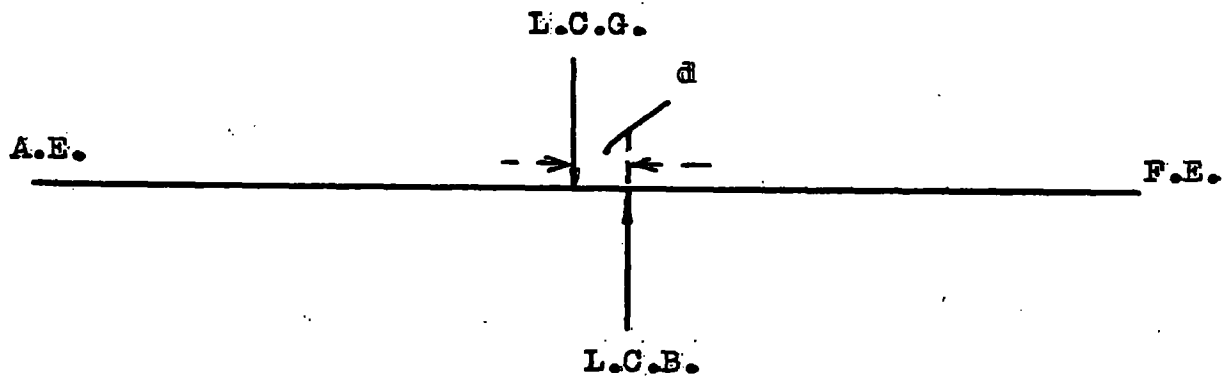


Fig. 25.

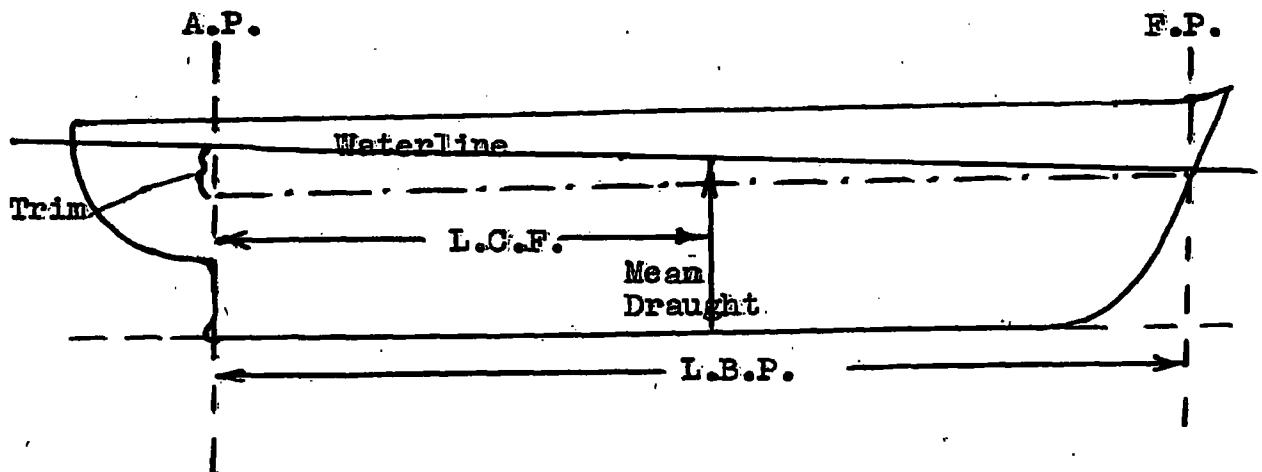
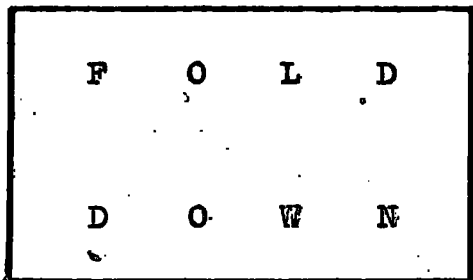


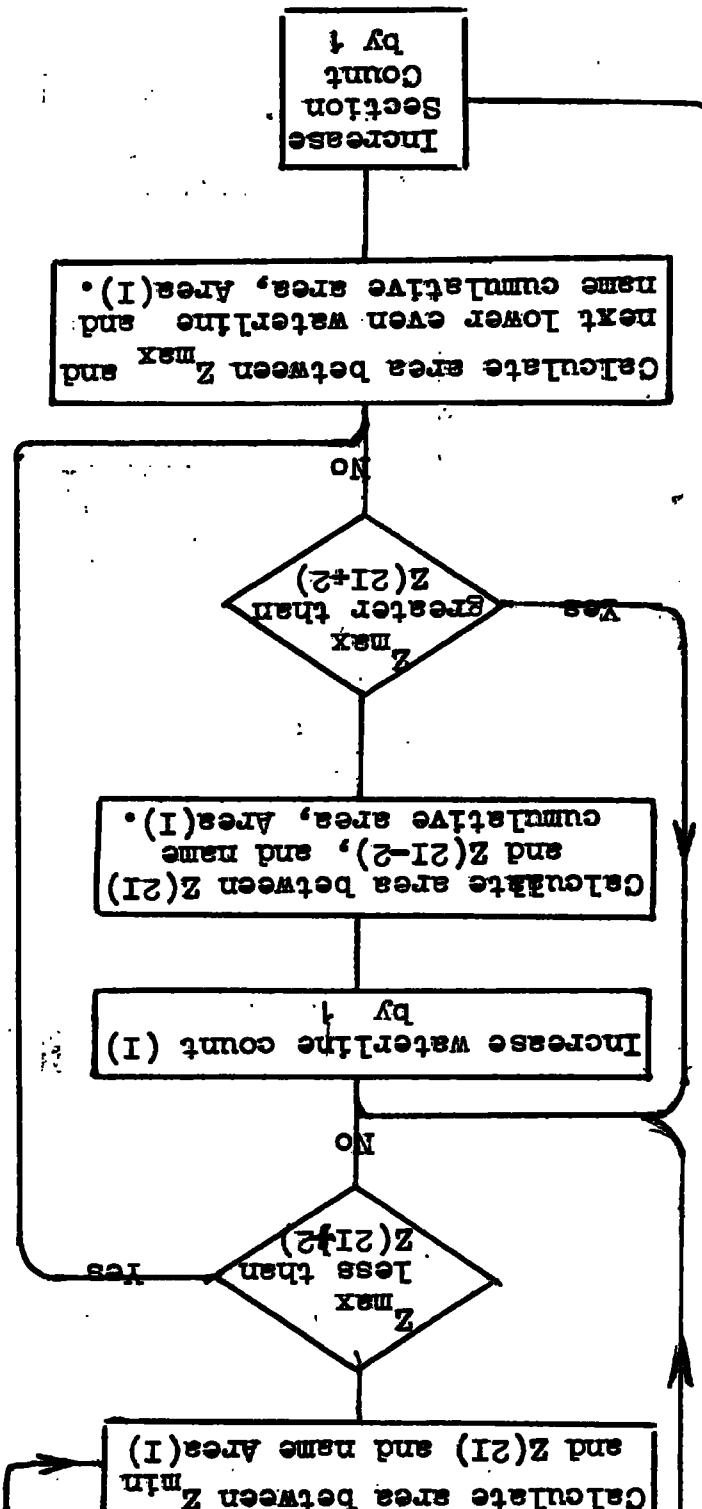
Fig. 26.

FLOW CHART

(Section 5).

SECTIONAL AREAS



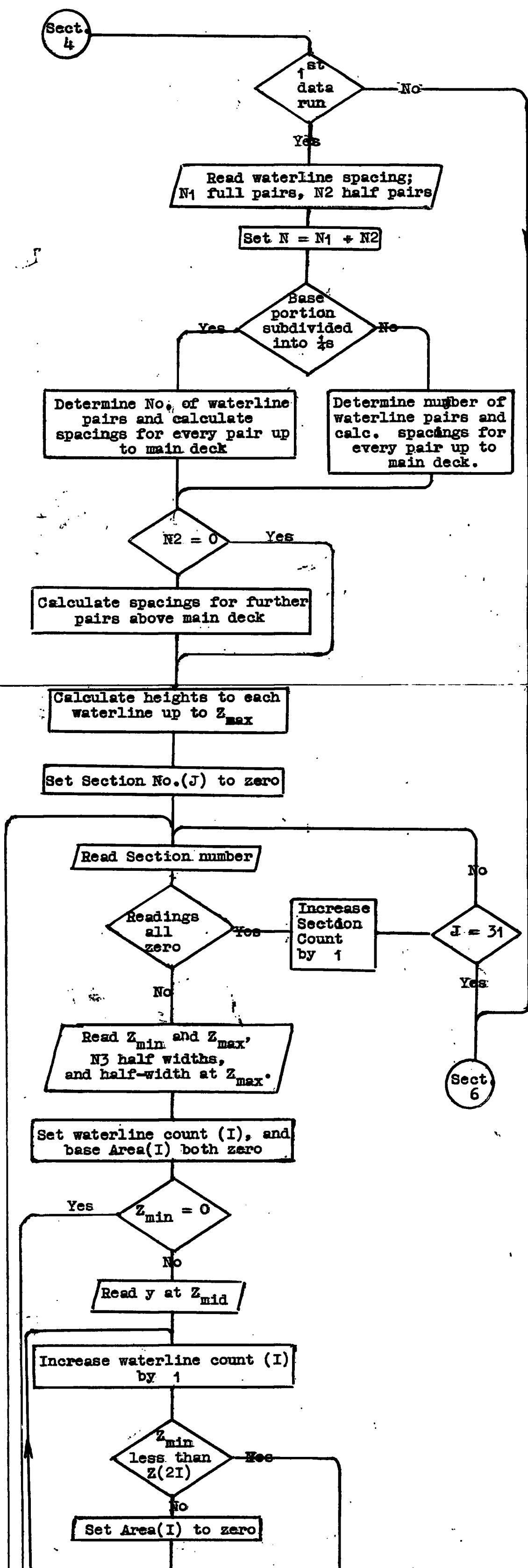


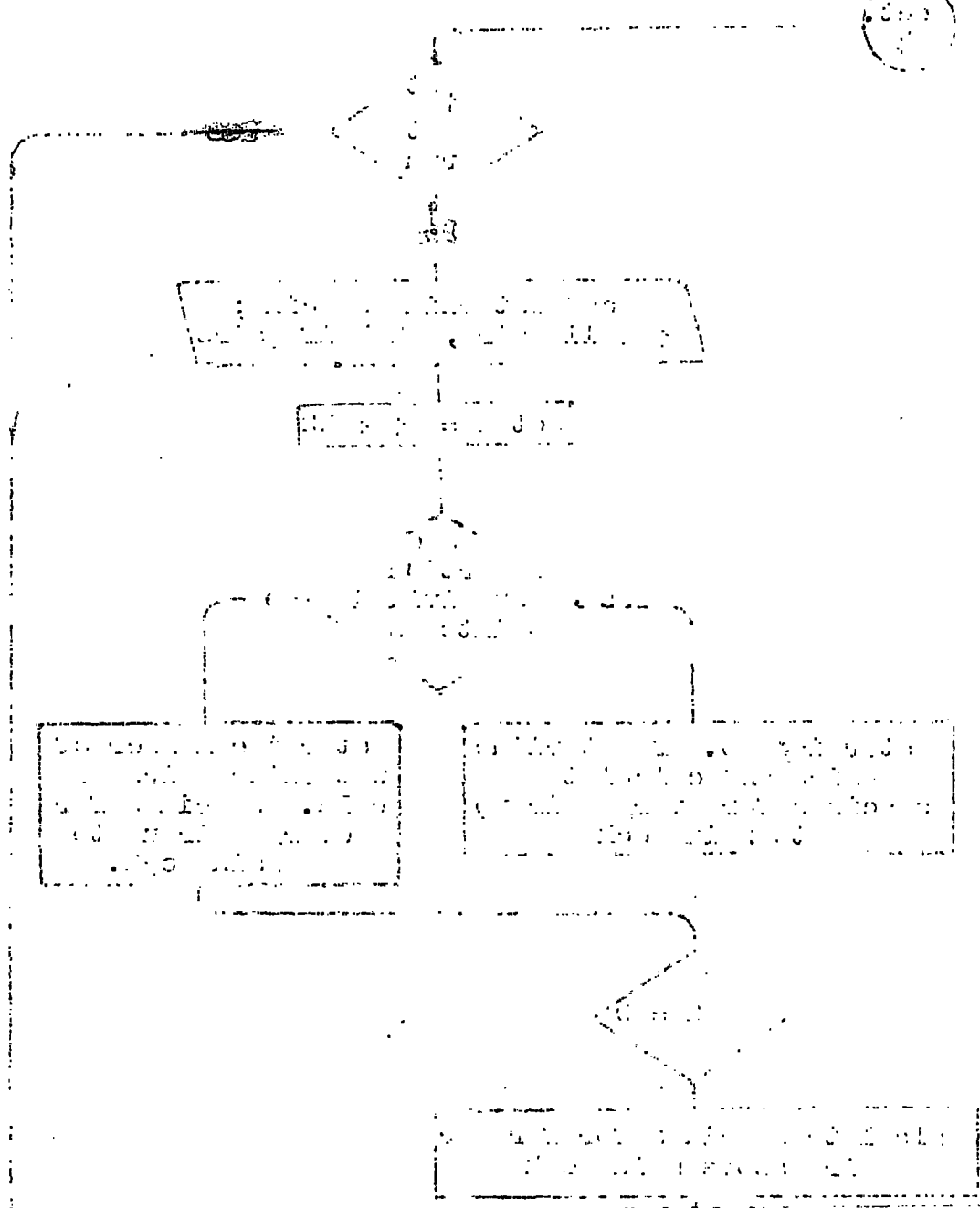


FLOW CHART (Section 5)

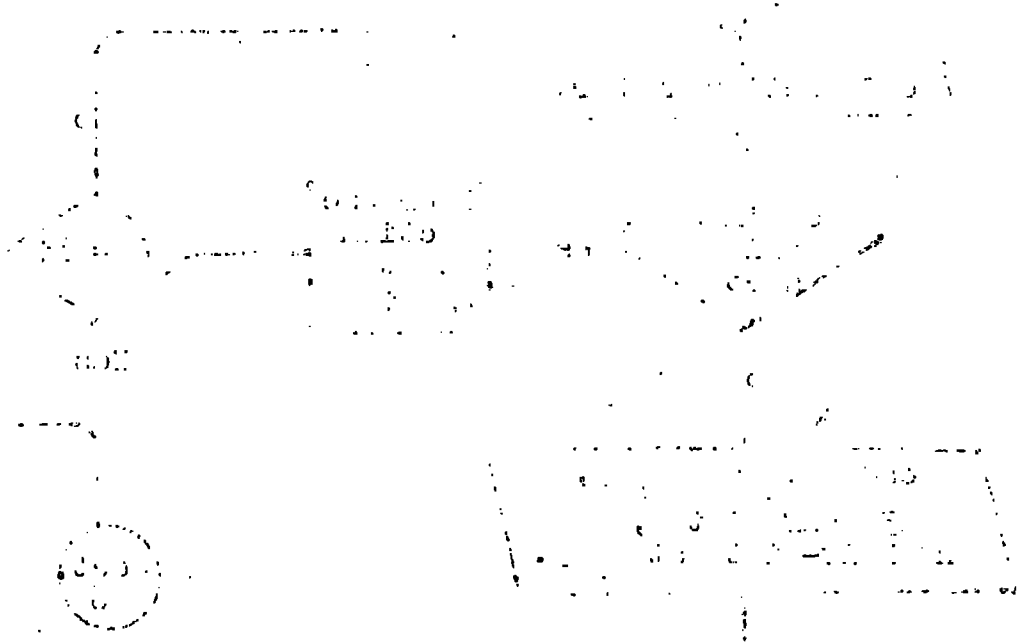
(Section 5).

CALCULATION AND STORAGE OF IMMERSED  
SECTIONAL AREAS.





Waterline up to  
of



Waterline up to  
of

Waterline up to  
of

Waterline up to  
of

Waterline up to  
of

Waterline up to  
of

PART 5

CALCULATION AND STORAGE OF IMMERSED SECTIONAL AREAS

TO EACH EVEN WATERLINE

This portion of the programme is an adaptation of Elliott Application programme LSB 3A. LSB 3A was sent to the computing laboratory of Sunderland Technical College in June 1963, for comments, and possible improvements. The writer amended the programme to produce more accurate results from lower waterline data, and the small portion of the programme affected is now used as a basis in this Longitudinal Strength programme to compute and store immersed sectional areas to each even waterline.

Process Used

The ship is divided as follows: Horizontal waterlines are taken, spaced at distance 'h' apart, and arranged so that an even number of spaces (2n) from the base reaches either to the upper deck at side or to a point just below the upper deck, at its lowest point.

$$\text{i.e. } (2n).h \leq \text{Height to main deck} < (2n + 1).h.$$

The two lowest divisions may be subdivided in two ways, by setting a control constant, according to the shape of the bottom of the ship. For ships with flat (horizontal) bottoms, the waterlines should be, from the base upwards ; 4 spacings of  $h/4$  and 2 spacings of  $h/2$ . The alternative is 4 spacings of  $h/8$ , 2 of  $h/4$  and 2 of  $h/2$ .

Above the (2n)th waterline further waterlines are taken with spacings of  $h/2$  until the maximum height of the ship is included in the last pair. See Fig. 27(a).

All waterlines (lettered  $i$ ) are now grouped in pairs lettered  $q$ ) starting from the base line. We have, therefore:-

1 pair (subdivided as above),

$N_1$  pairs (of width  $2h$ .) taking us up to the upper deck at side,

$N_2$  pairs (of width  $h$ ) taking us to the maximum height of the vessel.

The maximum value of  $q$  for the whole ship is  $N$ .

<u>Spacings of waterlines</u>	<u>Waterline number, <math>i</math>.</u>	<u>Group number, <math>q</math>.</u>
(from $i = 0$ to $i = 2N$ )	(from base upwards)	(from base upwards)

Method 1.  $N = N_1 + N_2 + 3$

$h/4$	1, 2, 3, 4.	1, 2.
$h/2$	5, 6.	3
$h$	7, 8 ... $(2N_1+6)$	4, 5 .... $(N_1+3)$
$h/2$	$(2N_1+7), (2N_1+8) \dots 2N$	$(N_1+4) \dots \dots \dots N$

Method 2.  $N = N_1 + N_2 + 4$

$h/8$	1, 2, 3, 4.	1, 2.
$h/4$	5, 6	3
$h/2$	7, 8	4
$h$	9, 10 ... $(2N_1+8)$	5, 6 .... $(N_1+4)$
$h/2$	$(2N_1+9), (2N_1+10) \dots 2N$	$(N_1+5), (N_1+6) \dots N$

Values of  $h$ ,  $N1$ ,  $N2$  and the control for choice of Method 1, or Method 2 ( $Q1$ ) are read in. Using Vary loops, heights to all waterlines ( $i$  values) are computed, using F.Pt. variable  $Z$ , and areas to all even waterlines computed and stored.  $O(25J + P)$ , ( $P = q$ ), where  $J$  takes values  $0 - 30$  in the Loop.

The calculations are performed as follows:-

The shape of the vessel is defined by the ordinate  $g_{xz}$ , (the half width) given for each waterline ( $i$ ). The integrals are calculated using Simpson's Rule and trapeziums. At the upper and lower edges, however, a slight variation is necessary. The half-width  $g_{max}$  must be given at the value of  $z_{max}$ . It is then assumed that the section curve is replaced by a straight line, and the area is obtained by treating the top part as a trapezium between the limits  $z_q$  and  $z_{max}$ . ( $z_q < z_{max} \leq z_{q+1}$ ). At the lower edge, for  $z_{min} > 0$ , a half width  $g_{mid}$  is required such that

$$g_{mid} = g \left( \frac{z_q + z_{min}}{2} \right)$$

where  $(z_q - 1) \leq z_{min} < z_q$  (See fig. 27b)

The integration of this portion is made between the limits  $z_{min}$  and  $z_q$ .

The areas are calculated according to the formulae:-

For a given q

$O(25J + P) =$

$z_{\min} \geq z_q$	0
$z_{q-1} < z_{\min} < z_q$	$2 \left[ \frac{1}{3} \left\{ \frac{z_q - z_{\min}}{2} \right\} (4y_{\min} + y_q) \right]$
$z_{\min} < z_{q-1}$ and $z_q \leq z_{\max}$	$O_{q-1} + 2 \left[ \frac{1}{3} (\delta z_i) (y_{q-1} + 4y_{q-2} + y_q) \right]$
$z_q < z_{\max} < z_{q+1}$	$O_q + \left[ 2(z_{\max} - z_q) \left( \frac{y_{\max} + y_q}{2} \right) \right]$

Areas are thus calculated to every even waterline for every section, where P is the waterline count in pairs.

e.g.  $O(25J + P)$  where J is 3 and P is 7 is the area at Section 3 up to  $q = 7$  (or  $i = 14$ ).

(The use of P in these notes is purely for clarity, but the programme, in fact, overwrites I as the count variable for the waterline pairs).

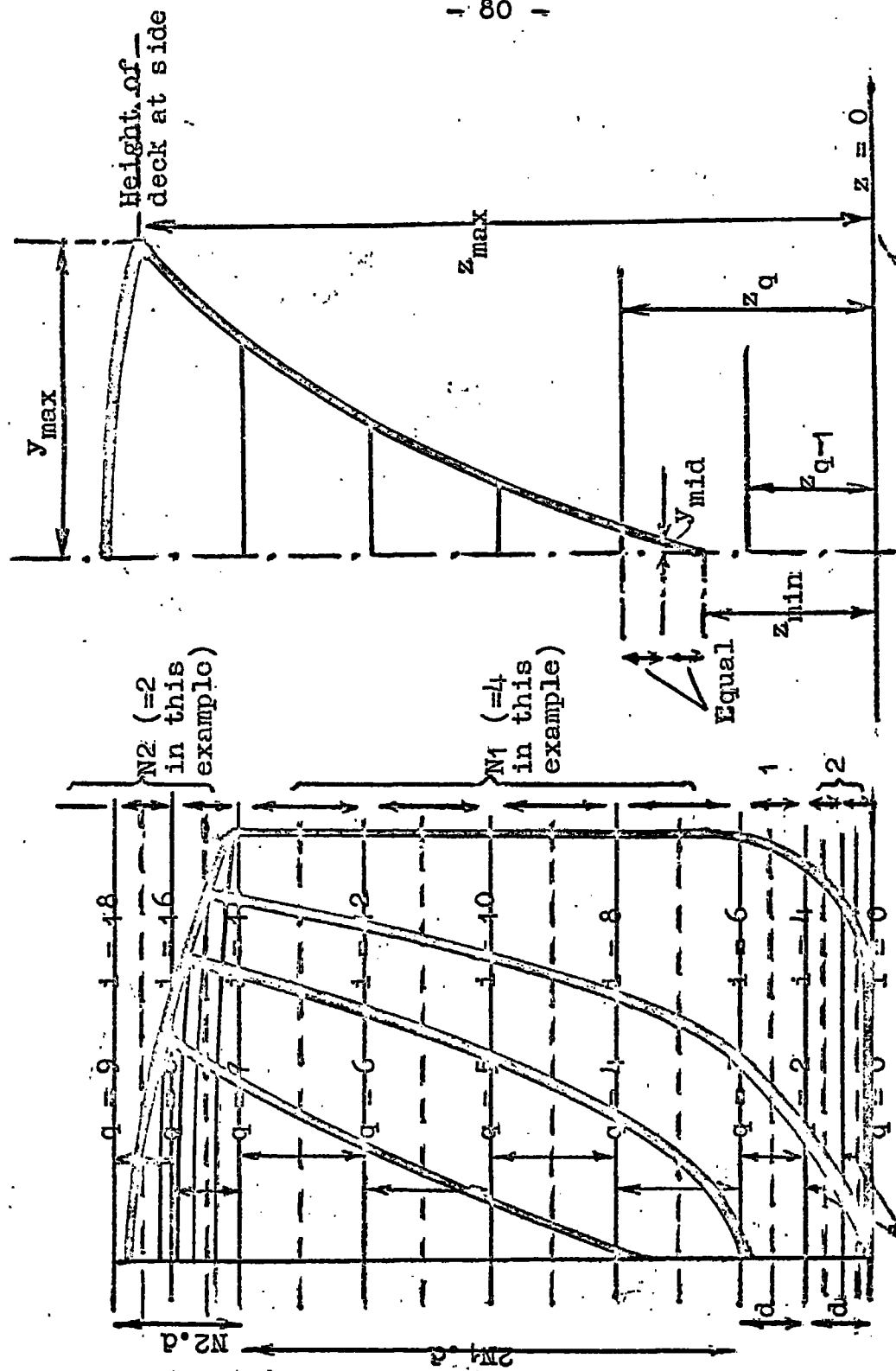


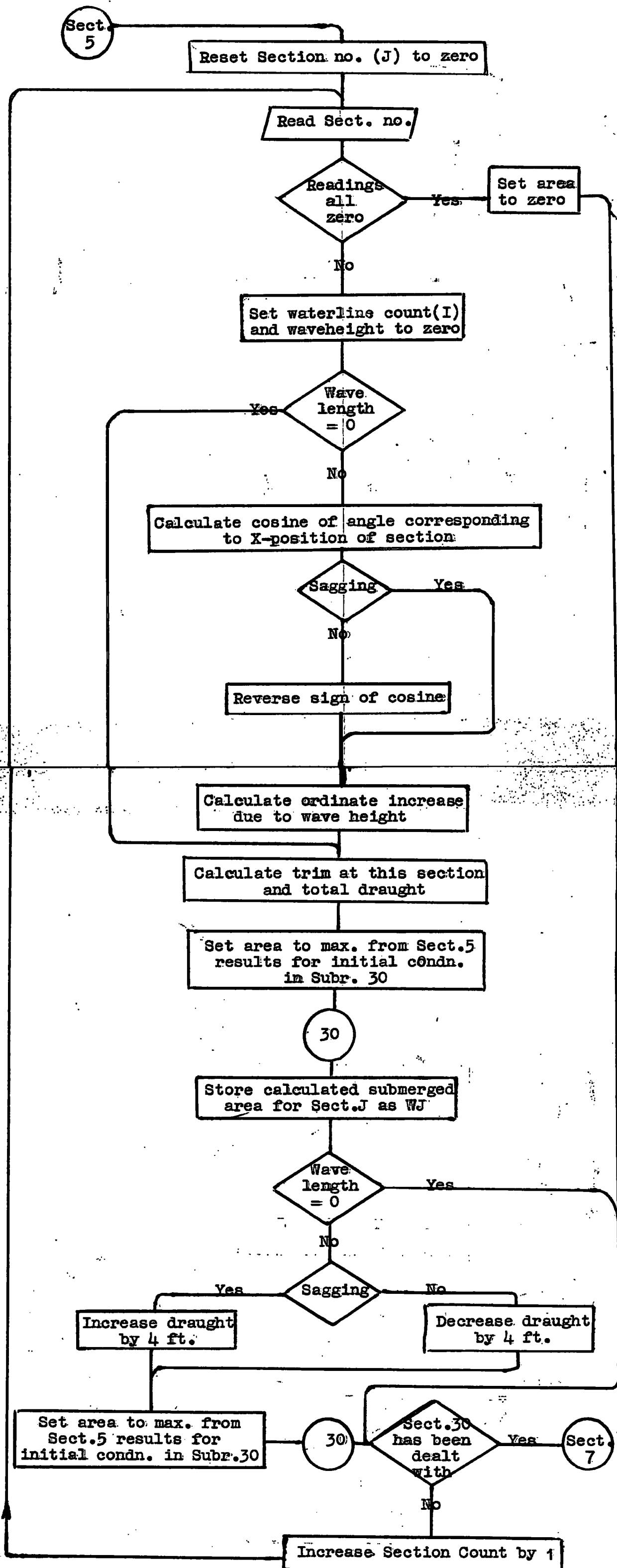
Fig 27(b)

Fig 27(a) Waterline spacing.  
(Method 1. See p77)

FLOW CHART (Programme Page 17)

(Section 6).

DRAUGHTS AND IMMERSED SECTIONAL AREAS

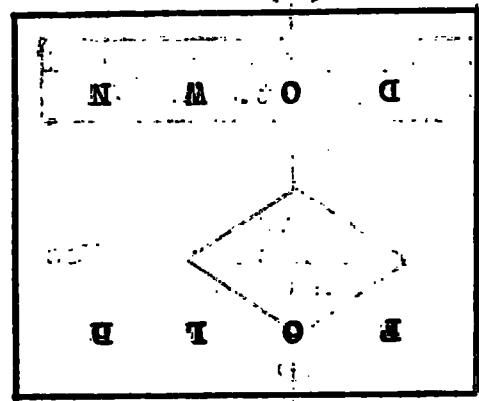




(Section 6)

DETERMINATION OF DRAUGHTS AND CONSEQUENT IMMERSION

SECTIONAL AREAS AT EACH STATION



SECTIONAL AREAS AT EACH STATION

SECTIONAL AREAS AT EACH STATION

PART 6

DETERMINATION OF DRAUGHTS AND CONSEQUENT IMMERSED

SECTIONAL AREAS AT EACH STATION

Stations are taken in order, and the calculation for each station completed before dealing with the next station.

The draught to the still water level is determined (so far as Trim is concerned) as mentioned in Part 4. The programme provides, however, for the vessel to be in a sine wave, and the amended draughts to the water surface are now determined if this condition applies. For each station in turn, the draught is found by adding to the still water draught the corresponding ordinate of the sine wave.

The appropriate ordinate for a particular distance  $\underline{x}$  from the stern is given by the formula:-

$$\text{Ordinate} = \pm a \cos \frac{2\pi(\underline{x} - \underline{x}')}{\lambda}$$

where  $a$  is the amplitude and  $\underline{x}'$  the distance from the rearmost point of stern to the position of the first trough or crest.

Wave height,  $\underline{a}$ , length,  $\lambda$ , and position relative to the ship,  $\underline{x}'$ , may be varied as required, but in these following examples, only two conditions have been taken, i.e. wavelength equal to  $L_{BP}$  and (i) first wave crest at the A.P., and (ii) first wave trough at the A.P.

Referring to Fig. 28 (a) and (b), and taking the wavelength to be  $L_{BP}$  the angular measure  $\theta^c$  at any distance  $\underline{x}$  is  $\frac{2\pi(\underline{x} - L1)}{L_{BP}}$ .

Since zero angle corresponds to the position of the crest (if in 'sagging' condition, or the trough in the 'hogging' condition), then in this example zero angle is at the A.P. The angle corresponding to the extreme stern will be found from the following steps:-

$$X = XJ - L_1 \quad \text{i.e. } 0 - L_1 \text{ or } -L_1$$

Therefore 
$$\theta^c = \frac{2\pi(-L_1)}{\lambda}$$

and the ordinate to be added to the still-water height is

$$\cos \frac{2\pi(-L_1)}{\lambda} \cdot (\text{Amplitude}) .$$

Similarly the ordinate at any position XJ is given by

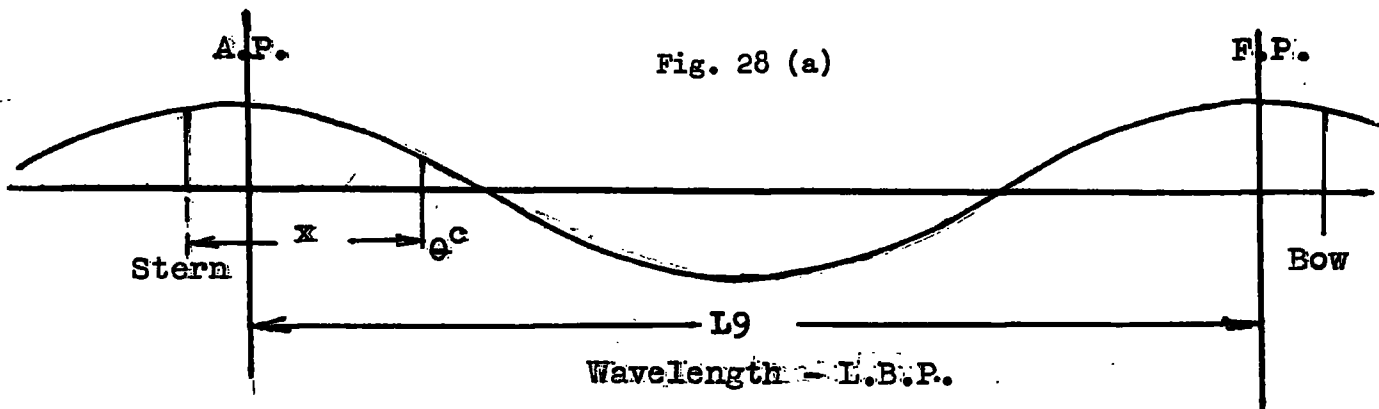
$$\cos \frac{2\pi(XJ - L_1)}{\lambda} \cdot (\text{Amplitude}) .$$

The Sectional area cut off at this total draught is calculated for each station respectively, and will be understood from fig. 29. Submerged areas are stored using F.Pt. variable WJ, where J is the station number.

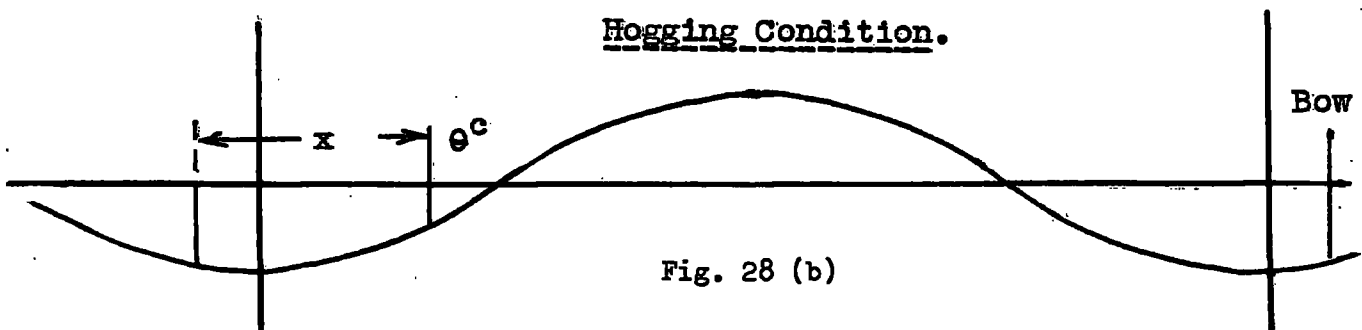
Again, where a sine wave is considered, and not just the still-water line, the above procedure (for finding immersed areas) is repeated for positions of the wave  $\pm 4$  ft. from the basic position (for use in Muckle's method) the plus sign being operative where the 'sagging' condition is being considered, and the minus where we have 'hogging'. Such areas are stored as F.Pt. variable UJ.

We are now ready to calculate the volume displaced and where the sine wave is encountered, the first and second moment functions, for use in Muckle's method. The volume of displacement is very simply found at each station, by considering unit length at each station. The immersed area is now a measure of this volume and division by 35 gives the Buoyancy in ton/ft. at the point. This is repeated at each of the 31 stations, and where there is no sine wave, the interpolation routine is entered to obtain the buoyancy values at each one-hundredth of the ships length.

Sagging Condition



Hogging Condition.



Three point Lagrange interpolation is used. The first and last of the 31 stations which have a reading greater than zero are found, and these are numbered I and J. The interpolation is then carried out between stations  $(I - 1)$  and  $(J + 1)$ .

After interpolation the total displacement is found (using Simpson's method). The value obtained may differ slightly from the known total buoyancy and if so, the calculated value is adjusted by adding, algebraically, small equal amounts to each ordinate. This may still leave the calculated L.C.G. in error (marginally) so ordinates are adjusted in the same manner as that employed in Lloyd's continuous weight distribution. See page 45.

Determine horizontal shift (if any) of L.C.G.  
Name L8

Determine the horizontal shift of each ordinate  
of buoyancy, from the ratio  $L8/H$

Calculate the new X values for each  
ordinate after shifting.

58

(Obtain 100 new  
D values, at steps  
 $1/100$  L.O.A.)

Sum corrected ordinates in pairs, and  
project forward, progressively, as  
final D values.

table  
required

No

Yes

Print Title and output table of values

Sum ordinates and calculate  
total displacement, on the final  
D values.

29

(Final  
calculated LCB  
position).

Print Titles and values for  
Displacement and L.C.B.

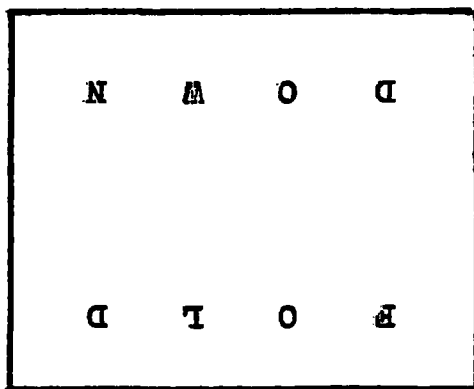
Graphs  
required

No

Yes

Output graph tape.

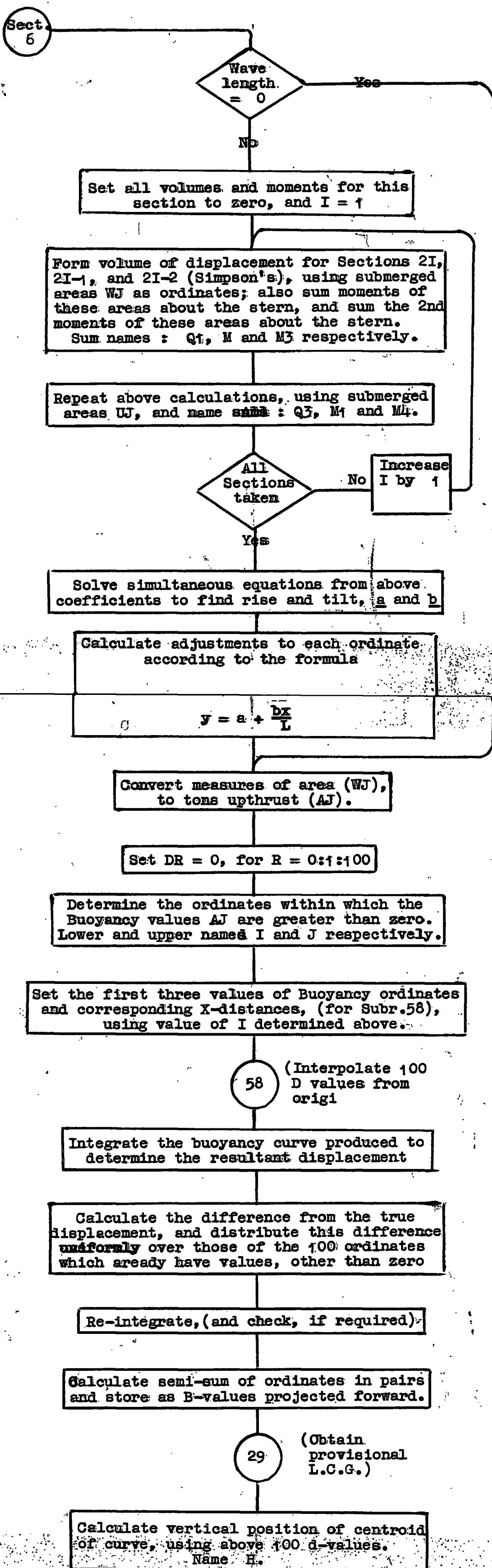
Sect.  
8



FLOW CHART (Programme Page 18)

(Section 7).

ADJUSTMENT OF SUBMERGED AREAS USING MUCKLE'S METHOD  
AND DETERMINATION OF BUOYANCY ORDINATES.





PART 7

MUCKLE'S METHOD FOR SUPERIMPOSED SINE WAVE:

ADJUSTMENT OF BUOYANCY ORDINATES FOR CORRECT

DISPLACEMENT AND L.C.F.

If the waterline is not a straight one, a further calculation must be performed to find the true buoyancy at each station. When a sine-wave is superimposed upon the still-water line in this fashion, the displacement cut off by the wave is not the required displacement. The wave must be adjusted for the required displacement, and so that the centre of buoyancy is in the same vertical line as the centre of gravity. The method used in the programme is one described by W. Muckle in "The Ship Builder and Marine Engine-BUILDER", February 1954 from which the following notes are taken.

If 'sagging' is being considered, then the wave must be raised and tilted. The amount which the wave must be raised at any position in the length of the ship may be written:

$$y = a + \frac{bx}{L},$$

where 'a' and 'b' are constants and x is measured from the rearmost point of the stern; L is the length overall of the vessel.

For any given station, let the area cut off by the wave, before adjustment, be  $A_0$ , and let the area at a position 4 ft. above that be  $A_4$ . An examination of the Bonjean curves shows that the curve between these two positions could well be represented by a straight line, so

that the area at any point 'y' above the initial wave position will be: (See fig. 29)

$$A_0 + y \frac{(A_1 - A_0)}{l} = A_0 + \left[ a + \frac{bx}{L} \right] \left[ \frac{A_1 - A_0}{l} \right]$$

The total volume after the wave has been shifted must be equal to the required volume 'V' corresponding to the loading condition.

$$\text{i.e. } \int A_0 dx + \int \left[ \left[ a + \frac{bx}{L} \right] \left[ \frac{A_1 - A_0}{l} \right] \right] dx = V.$$

This may be written:

$$\int A_0 dx + a \int \left[ \frac{A_1 - A_0}{l} \right] dx + b \int \frac{x}{L} \left[ \frac{A_1 - A_0}{l} \right] dx = V \dots\dots (i)$$

Similarly the Moment of the area about the stern is given by:

$$A_0 \cdot x + \left[ a + \frac{bx}{L} \right] \left[ \frac{A_1 - A_0}{l} \right] x ,$$

and the Moment of the Volume must equal  $V \cdot \bar{x}$  where  $\bar{x}$  is the distance of the centre of buoyancy from the stern.

Therefore,

$$\int A_0 \cdot x dx + \int \left[ \left[ a + \frac{bx}{L} \right] \left[ \frac{A_1 - A_0}{l} \right] x \right] dx = V \cdot \bar{x}$$

which may be written:

$$\int A_0 \cdot x dx + a \int x \left[ \frac{A_1 - A_0}{l} \right] dx + b \int \frac{x^2}{L} \left[ \frac{A_1 - A_0}{l} \right] dx = V \bar{x} \dots (ii)$$

Equations (i) and (ii) will provide the solutions to the two unknowns 'a' and 'b'.  $\int A_0. dx$  is the volume function and in the programming of (i) and (ii) above is the F.Pt. variable Q1.

$\int A_0.x dx$  is the 1st moment ..... M.

$\int \left( \frac{A_4 - A_0}{4} \right) dx$  is the volume function of the differences .... Q3.

$\int x \left( \frac{A_4 - A_0}{4} \right) dx$  is the difference in 1st moment functions ... Q2.

$\int x^2 \left( \frac{A_4 - A_0}{4} \right) dx$  is the difference in 2nd moment functions .. Q5.

If 'hogging' is being considered, then the wave must be lowered and tilted. The amount by which the wave must be lowered at any point in the length of the ship is, as before, given by  $y = a + \frac{bx}{L}$ , and the same equations hold as for 'sagging'. Of course,  $A_4 - A_0$  will be negative, since  $A_4$  is determined when the wave form is taken 4 ft. below the original position.

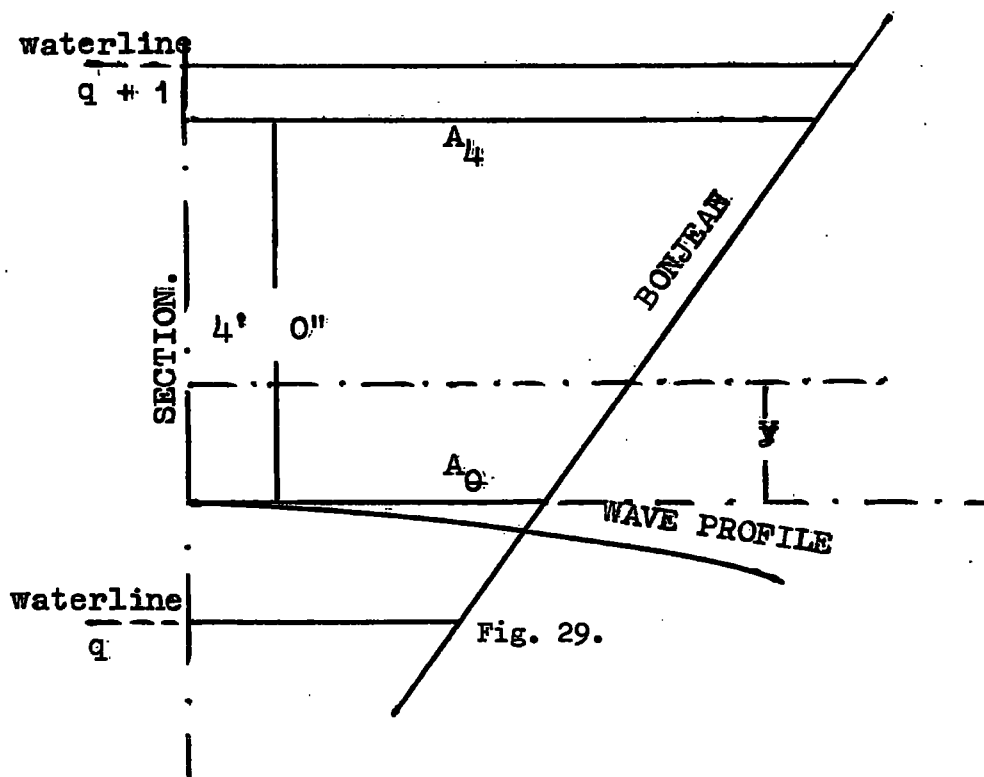
Having now found the true areas for the wave form condition, the buoyancy is found as previously mentioned (page 83) and the interpolation routine entered to find the buoyancy at every one-hundredth division of the ship's length.

In spite of Muckle's method being applied to the displacement and L.C.B. position, it is quite likely to leave the final results in slight error. This slight error, if any, is finally corrected by the method outlined on pages 84 and 45.

Buoyancy ordinates are now stored as DR and are printed out if required. (Ordinates are Projected forward as before). Graph output is optional.

Pages 89-92 show the Bonjean input data extracted from the complete Hull Definition Data Sheet as shown on page 169. After the initial BONJEAN head data, data is read vertically, column by column.

Page 93 shows the tabulated output for A842 and on page 94 may be seen the corresponding graph.



- 89 -

(H - waterline spacing  
(Q1 - choice of  $\frac{1}{8}$ s or  $\frac{1}{4}$ s.  
(N1 - pairs of full spacings  
(N2 - pairs of half spacings

3 .25 7 3 - - - -

(S19 - station number.  
(P(J+5) - zero if no half widths.  
(Z(51+J) - Z min.  
(Z(82+J) - Z max

0 0 - - - -

1 1 34.313 49.407  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2.25 5.167  
7.583 9.75 11.646 0 0 0 0 0 0 (Half-widths:  
12.447 1.396 - - - - - 27 in this case.  
- - - - - (G52 - G max  
- - - - - (G51 - G mid

2 1 29 49.290  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1.573 4.88 7.969  
10.677 13.031 15.063 16.813 0 0 0 0 0 0  
17.465 1.037

3 1 26.292 49.181  
0 0 0 0 0 0 0 0 0 0 0 0 0 1.38 5.162 8.755  
11.901 14.583 16.932 18.906 20.589 0 0 0 0 0 0  
21.184 2.917

4 1 24.304 48.985  
0 0 0 0 0 0 0 0 0 0 0 0 4.229 8.234 11.969  
15.130 17.802 20.094 22.042 23.703 0 0 0 0 0 0  
24.196 4.55

5 1 21.865 48.740  
0 0 0 0 0 0 0 0 0 0 0 3.365 7.667 11.693  
15.412 18.568 21.214 23.458 25.37 27.042 0 0 0 0 0  
27.395 1.750

6 1 0 48.598  
1.042 1.083 1.109 1.12 1.13 1.146 1.162 1.182 1.208  
1.245 1.557 3.162 6.802 10.885 14.839 18.427 21.479  
24.078 26.271 28.12 29.745 0 0 0 0 0 0  
30.021

7 1 0 48.48  
1.047 1.51 1.813 2 2.151 2.385 2.583 2.917 3.281  
3.807 4.818 6.802 10.109 13.932 17.702 21.109 24  
26.505 28.625 30.391 31.912 0 0 0 0 0 0  
32.124

8 1 0 48.394  
1.406 2.063 2.537 2.880 3.172 3.625 4.005 4.651 5.354  
6.37 7.901 10.219 13.313 16.880 20.401 23.521 26.292  
28.646 30.641 32.281 33.656 0 0 0 0 0 0  
33.818

9 1 0 48.25  
2.12 3.469 4.219 4.813 5.307 6.162 6.88 8.224 9.687  
11.453 13.687 16.323 19.224 22.307 25.234 27.885 30.245  
32.255 33.932 35.255 36.313 0 0 0 0 0 0  
36.391

10 1 0 48.154  
3.13 5.266 6.245 7.037 7.724 8.875 9.922 11.964 14.073  
16.354 18.849 21.583 24.323 26.984 29.422 31.599 33.5  
35.083 36.344 37.333 38.115 0 0 0 0 0 0  
38.142

11 1 0 48.04  
6.406 9.724 11.182 12.313 13.307 15.099 16.698 19.615  
22.339 24.974 27.531 29.948 32.099 34 35.630 36.99  
38.104 38.927 39.526 39.969 40.276 0 0 0 0 0 0  
40.273

12 1 0 48.00  
11.078 15.0 16.854 18.302 19.542 21.662 23.448 26.542  
29.182 31.488 33.531 35.328 36.818 38.068 39.068 39.828  
40.354 40.693 40.875 40.974 41.00 0 0 0 0 0 0  
41

13 1 0 48.00  
21.552 26.24 28.281 29.807 31.037 32.969 34.479 36.693  
38.198 39.24 39.964 40.448 40.766 40.938 41 41 41 41  
41 41 41 0 0 0 0 0 0  
41

14 1 0 48  
30.813 34.547 36.12 37.24 38.109 39.349 40.146 40.88 4  
41 41 41 41 41 41 41 41 41 41 0 0 0 0 00  
41

21 1 0 53.809  
6.927 10.828 12.488 13.719 14.729 16.318 17.531 19.313  
20.516 21.422 22.115 22.698 23.208 23.672 24.125 24.578  
25.073 25.563 26.146 26.771 27.427 27.771 28.141 28.516  
0 0 0  
28.851

22 1 0 54.828  
2.74 5.656 7.031 8.052 8.88 10.208 11.219 12.687 13.67  
14.443 15.047 15.552 16 16.438 16.87 17.344 17.87 18.5  
19.104 19.849 20.672 21.109 21.568 22.047 22.583 0 0  
22.875



BUOYANCY CURVES ORDINATES (PROJECTED FORWARD).  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 0

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

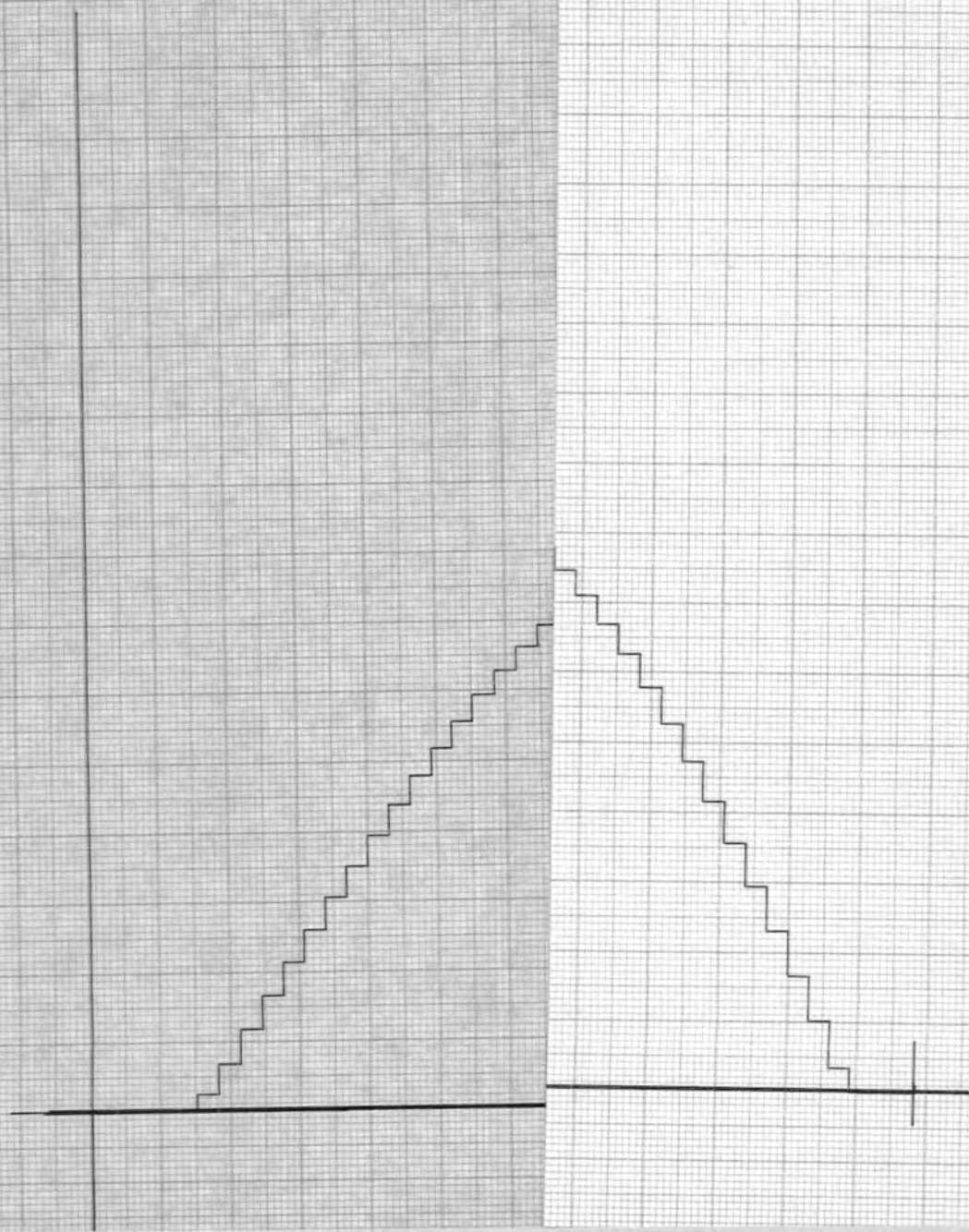
VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0  
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BUOYANCY CURVE ORDINATES

HORIZONTAL SCALE : 1 CM.

VERTICAL SCALE : 1 CM.



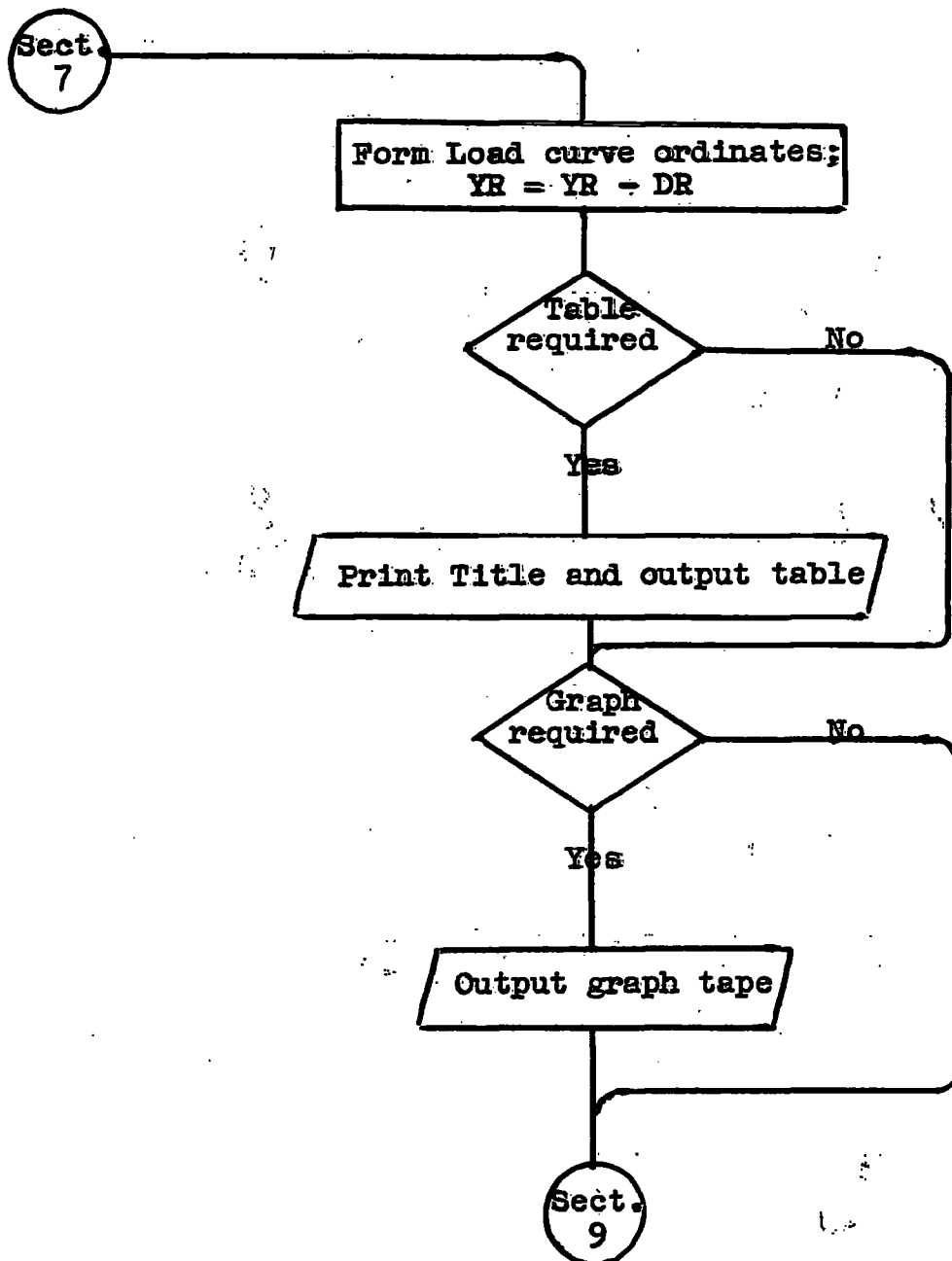
(STANDARD CITY CODE) - 1911

USE OF = 1911

STANDARD = 1911

(Section 8).

LOAD CURVE SECTION.



PART 8

LOAD CURVE

Load Curve ordinates are obtained by subtracting respectively the Total Weight ordinates from the Buoyancy ordinates. (These ordinates are projected forward like the Weight and Buoyancy ordinates). F.Pt. variable YR was used for Weight ordinates and DR for Buoyancy ordinates. The Load Curve ordinates are now held as  $YR(YR = YR - DR)$  and printed out if required. Graph output of the Load Curve is available if required.

The Load Curve tables for A842 are on pages 96 (using Lloyd's method) and 96(a) (using Biles Coffin), and the corresponding graphs (green for Lloyd's method - red for Biles Coffin) are on page 97.

LOAD CURVE ORDINATES (PROJECTED FORWARD)

(BILES COFFIN DISTRIBUTION)

ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT
0	-0.16	1	-1.84	2	-4.09	3	-8.70
4	-19.00	5	-28.01	6	-31.59	7	-8.01
8	-8.54	9	-8.31	10	-8.03	11	-3.31
12	-1.10	13	-9.66	14	-14.67	15	-12.19
16	-8.79	17	-7.03	18	4.80	19	9.05
20	5.67	21	14.79	22	15.31	23	16.42
24	18.18	25	18.93	26	19.60	27	20.20
28	21.01	29	20.82	30	10.18	31	20.25
32	21.86	33	21.53	34	21.63	35	21.74
36	21.87	37	21.96	38	22.13	39	22.48
40	22.44	41	-68.66	42	-71.49	43	-70.99
44	-70.08	45	-81.50	46	10.95	47	19.35
48	20.02	49	19.52	50	19.36	51	19.19
52	19.01	53	18.82	54	18.85	55	18.91
56	11.22	57	19.02	58	18.64	59	18.16
60	17.98	61	17.81	62	17.65	63	17.49
64	17.57	65	16.93	66	13.32	67	-78.33
68	-74.32	69	-74.25	70	-73.72	71	-84.57
72	15.24	73	15.54	74	15.93	75	16.31
76	15.84	77	15.99	78	16.14	79	16.01
80	15.51	81	13.21	82	3.31	83	13.21
84	12.70	85	11.57	86	10.26	87	8.77
88	7.11	89	5.42	90	8.20	91	5.88
92	-9.77	93	-27.85	94	-16.83	95	-14.49
96	-12.02	97	-6.81	98	-3.28	99	-2.70
100	0.00						

Table 13(a).

LOAD CURVE ORDINATES (PROJECTED FORWARD)

(LLOYD'S DISTRIBUTION)

ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT
0	-0.69	1	-2.01	2	-3.72	3	-7.48
4	-17.62	5	-26.84	6	-30.60	7	-7.19
8	-7.88	9	-7.80	10	-7.65	11	-3.06
12	-0.95	13	-9.60	14	-14.70	15	-12.29
16	-8.95	17	-7.25	18	4.54	19	8.76
20	5.34	21	14.44	22	14.94	23	16.04
24	17.80	25	18.55	26	19.24	27	19.85
28	20.69	29	20.53	30	9.94	31	20.07
32	21.74	33	21.48	34	21.65	35	21.78
36	21.87	37	21.93	38	22.08	39	22.41
40	22.38	41	-68.71	42	-71.54	43	-71.03
44	-70.10	45	-81.51	46	10.95	47	19.36
48	20.04	49	19.56	50	19.41	51	19.25
52	19.08	53	18.90	54	18.94	55	19.01
56	11.34	57	19.15	58	18.78	59	18.31
60	18.14	61	17.99	62	17.84	63	17.69
64	17.78	65	17.15	66	13.53	67	-78.28
68	-74.43	69	-74.53	70	-74.17	71	-85.18
72	14.47	73	14.63	74	14.91	75	15.17
76	14.61	77	14.68	78	14.77	79	14.60
80	14.09	81	11.78	82	1.93	83	11.89
84	11.47	85	10.46	86	9.29	87	7.99
88	6.58	89	5.17	90	8.27	91	6.32
92	-8.94	93	-26.62	94	-15.17	95	-12.36
96	-9.40	97	-3.77	98	-0.96	99	-0.29
100	0.00						

Table 13.

LOAD CURVE ORDINATES (PROJECTED FORWARD)  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 23

HEIGHT OF Y-AXIS = 30

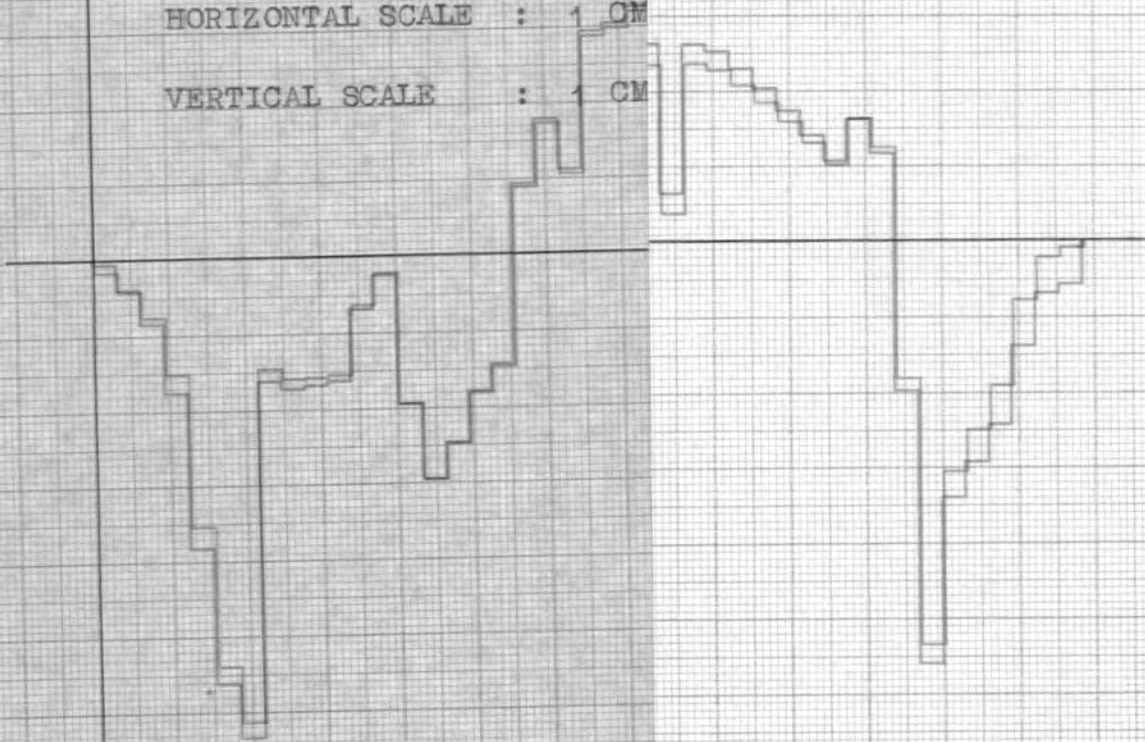
HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5.0  
-----

## LOAD CURVE ORDINATES (PRO)

HORIZONTAL SCALE : 1 CM

VERTICAL SCALE : 1 CM



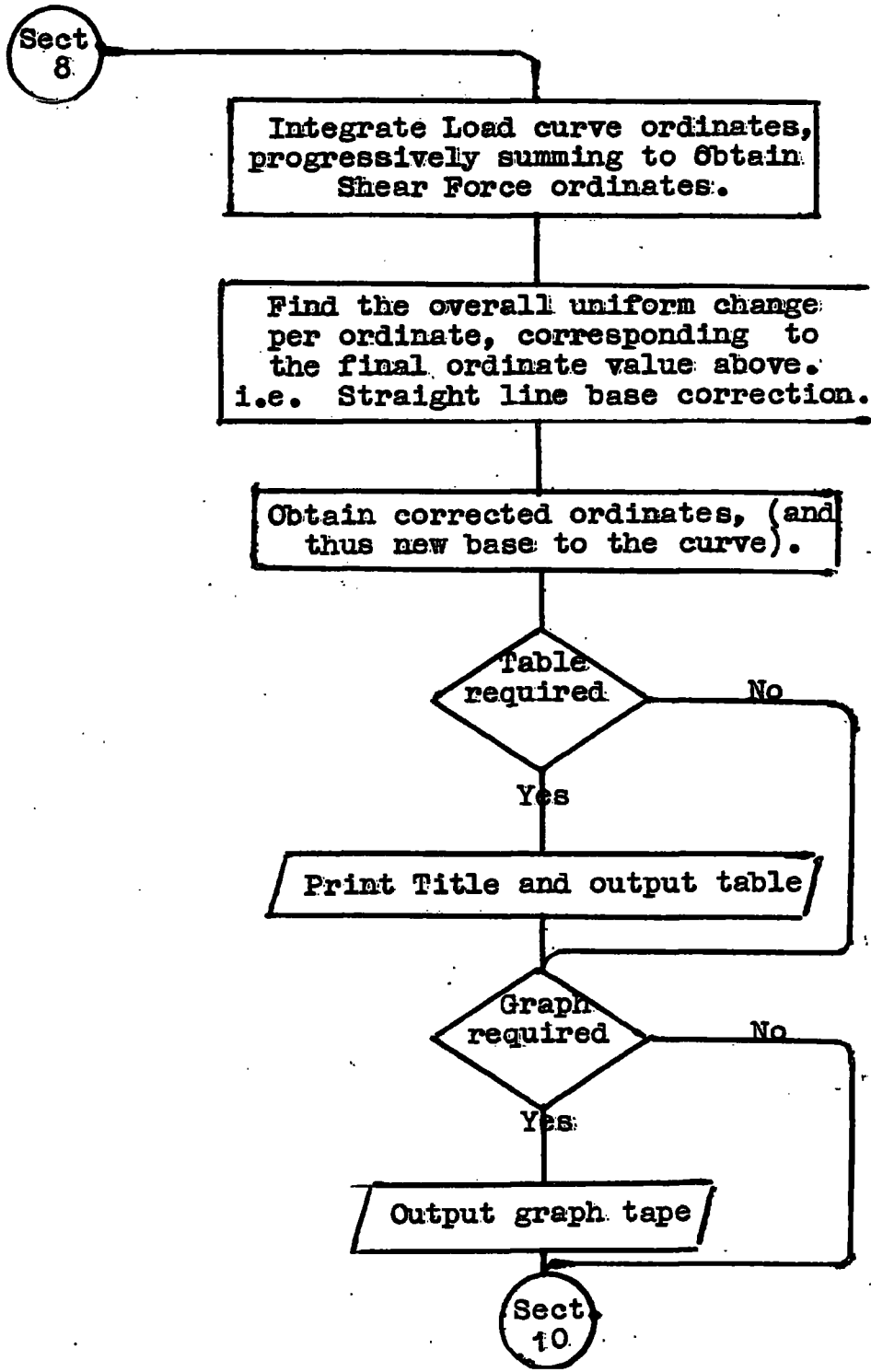
Note : Results using Lloy

### Results using Bile



(Section 9).

SHEAR FORCE CURVE SECTION.



PART 9

SHEAR FORCE (AND STRAIGHT LINE CORRECTION)

The shear force at any point (again held as YR) is the total weight to the left (or right) of the ordinate considered. The shear forces at the ends must be zero. Starting with zero shear force at ordinate number zero, the shear force at ordinate number one is the product of the Load at ordinate zero and the distance between the ordinates. The shear force at ordinate number two is the sum of that at ordinate number one together with the product of the load at ordinate number one and the distance between ordinates; and so on. To allow for any possible accumulation of error, any difference which may exist at ordinate No. 100, between the calculated shear force and zero, is made zero here and the remaining ordinates proportionately increased or reduced as the case may be. This means, in effect, tilting the base of the shear curve linearly, to obtain the true base.

On the ship under test, the error at the fore end (S100) was .39 tons, (by both methods), the maximum reading throughout the length of the vessel being of the order of 1400 tons.

Output of shear force tables is optional. The graph output for shear force is a continuous polygon, joining ordinate values by straight lines, and like the table is optional.

The Shear Force Curve table (using Lloyd's method) is on page 100

and the corresponding graph is on page 101, again in green. Results using Biles Coffin method are tabulated on page 100(a) and the appropriate graph superimposed in red on page 101.

SHEAR FORCE CURVE ORDINATES.

(BILES COFFIN DISTRIBUTION)

ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS
0	0	1	-1	2	-12	3	-38
4	-91	5	-208	6	-381	7	-576
8	-626	9	-678	10	-730	11	-779
12	-800	13	-806	14	-866	15	-957
16	-1032	17	-1086	18	-1129	19	-1100
20	-1044	21	-1009	22	-918	23	-823
24	-722	25	-610	26	-493	27	-372
28	-247	29	-118	30	11	31	74
32	199	33	333	34	466	35	600
36	734	37	869	38	1004	39	1141
40	1279	41	1418	42	994	43	553
44	115	45	-317	46	-820	47	-753
48	-633	49	-510	50	-389	51	-270
52	-151	53	-34	54	82	55	198
56	315	57	384	58	501	59	616
60	728	61	839	62	949	63	1058
64	1166	65	1274	66	1379	67	1461
68	978	69	519	70	61	71	-394
72	-915	73	-821	74	-726	75	-627
76	-527	77	-429	78	-330	79	-231
80	-132	81	-36	82	45	83	66
84	147	85	226	86	297	87	360
88	414	89	458	90	492	91	542
92	579	93	518	94	346	95	243
96	153	97	79	98	37	99	17
100	0						

Table 14(a).

SHEAR FORCE CURVE ORDINATES.

(LLOYD'S DISTRIBUTION)

ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS
0	0	1	-4	2	-17	3	-40
4	-86	5	-194	6	-360	7	-549
8	-593	9	-642	10	-690	11	-737
12	-756	13	-762	14	-821	15	-912
16	-988	17	-1043	18	-1088	19	-1060
20	-1006	21	-973	22	-884	23	-791
24	-692	25	-583	26	-468	27	-349
28	-227	29	-99	30	27	31	89
32	213	33	347	34	479	35	613
36	747	37	882	38	1017	39	1154
40	1292	41	1430	42	1006	43	565
44	126	45	-306	46	-809	47	-741
48	-622	49	-498	50	-378	51	-258
52	-139	53	-22	54	95	55	212
56	329	57	399	58	517	59	633
60	746	61	858	62	969	63	1079
64	1188	65	1298	66	1404	67	1487
68	1004	69	545	70	85	71	-372
72	-898	73	-809	74	-719	75	-627
76	-533	77	-443	78	-352	79	-261
80	-171	81	-84	82	-11	83	0
84	74	85	145	86	209	87	266
88	316	89	356	90	388	91	439
92	478	93	423	94	259	95	165
96	89	97	31	98	8	99	2
100	-0						

Table 14.

SHEAR FORCE CURVE  
-----

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 12

HEIGHT OF Y-AXIS = 30

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 100.0  
-----



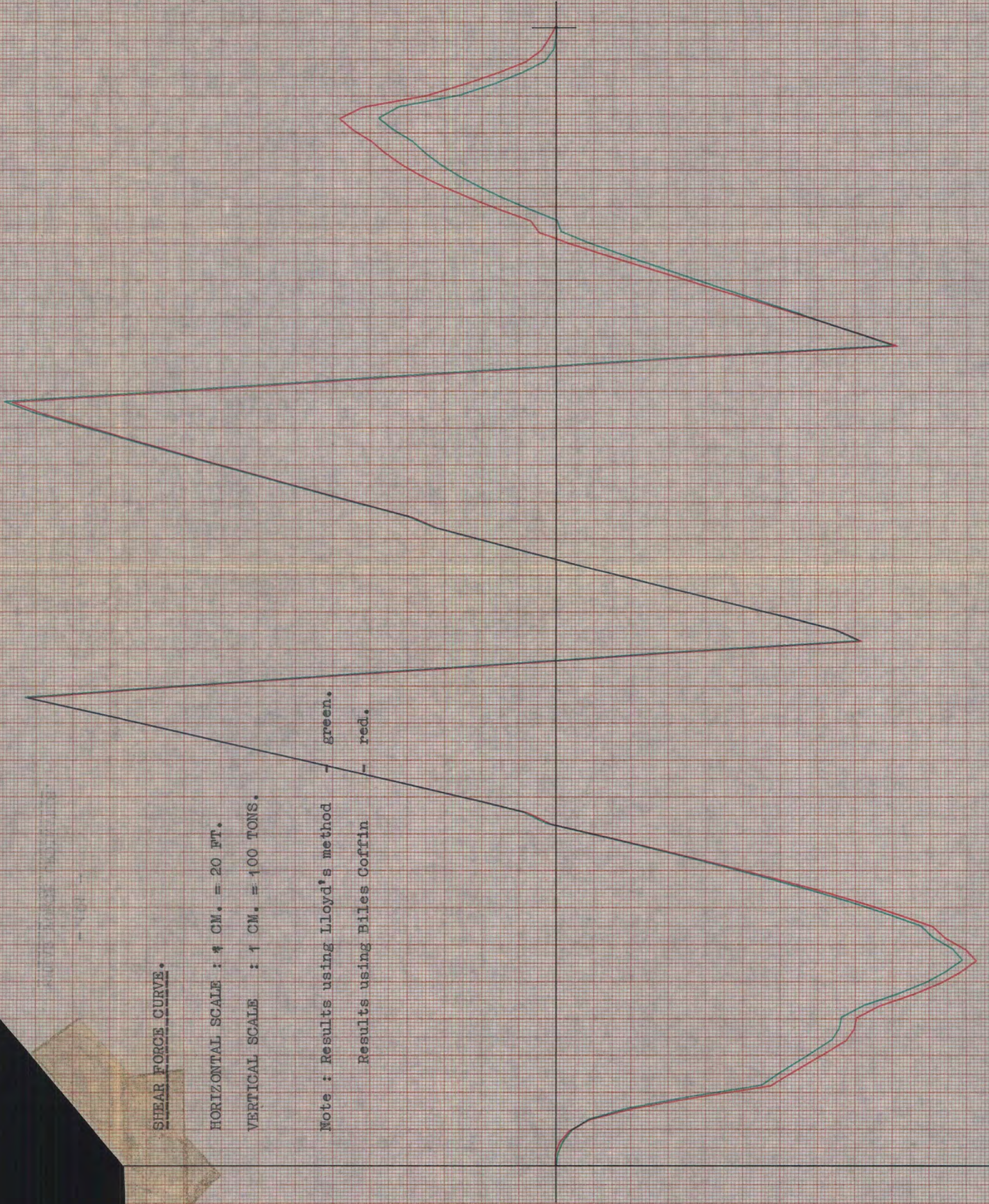


SHEAR FORCE CURVE.

HORIZONTAL SCALE : 1 CM. = 20 FT.

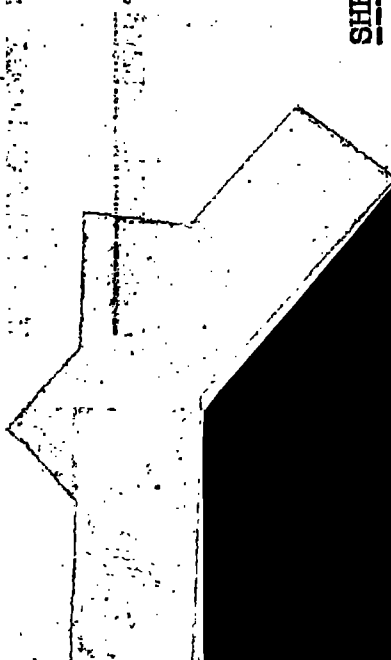
VERTICAL SCALE : 1 CM. = 100 TONS.

Note : Results using Lloyd's method - green.  
Results using Biles Coffin - red.





1.0014 2.0014 3.0014 4.0014 5.0014 6.0014 7.0014 8.0014 9.0014 10.0014  
 11.0014 12.0014 13.0014 14.0014 15.0014 16.0014 17.0014 18.0014 19.0014 20.0014  
 21.0014 22.0014 23.0014 24.0014 25.0014 26.0014 27.0014 28.0014 29.0014 30.0014  
 31.0014 32.0014 33.0014 34.0014 35.0014 36.0014 37.0014 38.0014 39.0014 40.0014  
 41.0014 42.0014 43.0014 44.0014 45.0014 46.0014 47.0014 48.0014 49.0014 50.0014  
 51.0014 52.0014 53.0014 54.0014 55.0014 56.0014 57.0014 58.0014 59.0014 60.0014  
 61.0014 62.0014 63.0014 64.0014 65.0014 66.0014 67.0014 68.0014 69.0014 70.0014  
 71.0014 72.0014 73.0014 74.0014 75.0014 76.0014 77.0014 78.0014 79.0014 80.0014  
 81.0014 82.0014 83.0014 84.0014 85.0014 86.0014 87.0014 88.0014 89.0014 90.0014  
 91.0014 92.0014 93.0014 94.0014 95.0014 96.0014 97.0014 98.0014 99.0014 100.0014

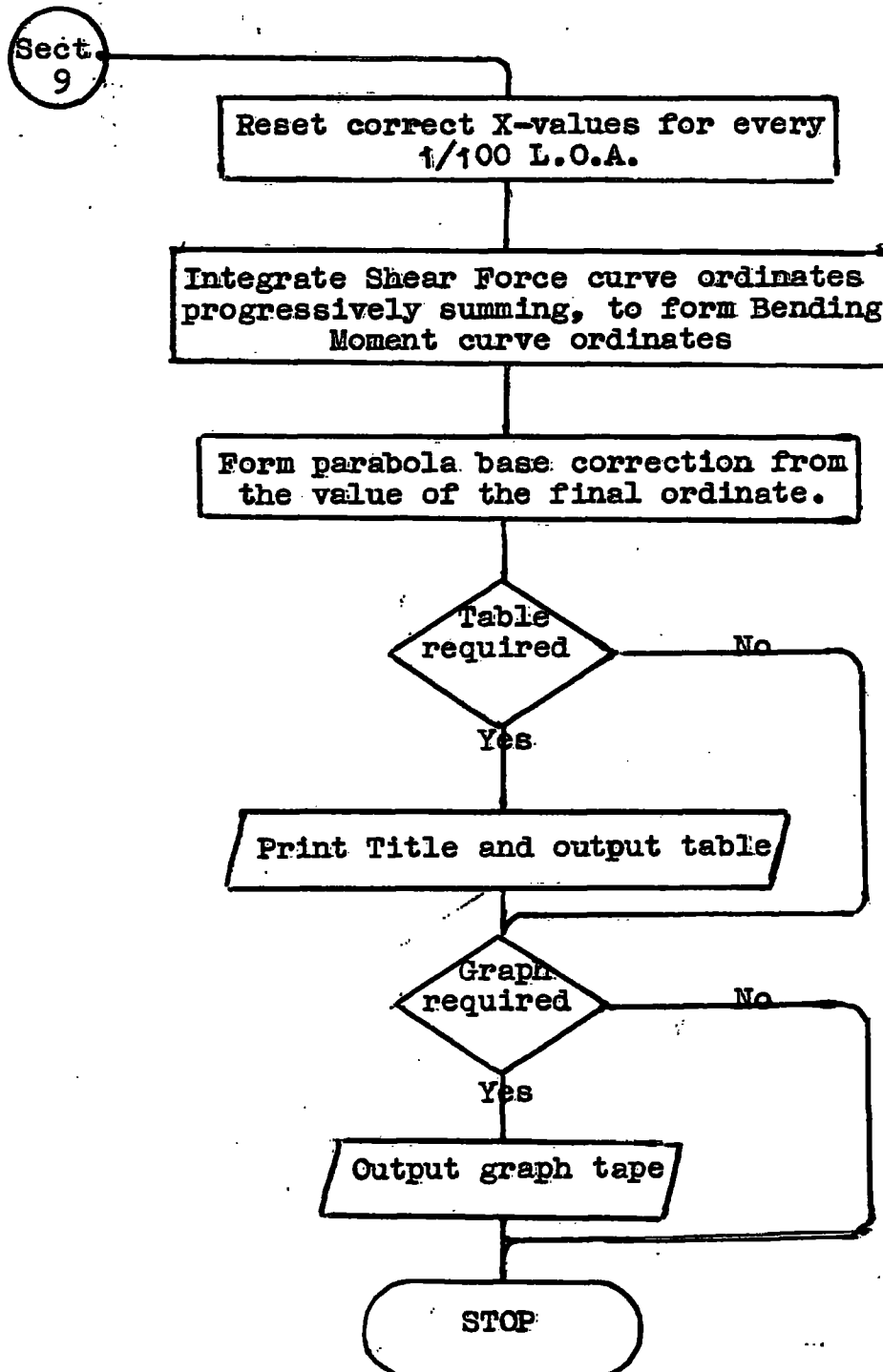


- 101 -  
SHEAR FORCE ORDINATES.



(Section 10).

BENDING MOMENT CURVE SECTION.



PART 10

BENDING MOMENT (WITH PARABOLA BASE CORRECTION)

The bending moment at any point (stored as BR) is the total area to the left (or right) under the shear force curve, up to the ordinate considered. That is, it is a second integration of the load curve.

The bending moments at the ends must be zero. Starting with zero bending moment at ordinate number zero, the bending moment at ordinate number one is the product of the mean shear force over the first division and the length of the division. The bending moment at ordinate number two is the sum of that at ordinate number one and the product of the mean shear over the second division and the length of the division; and so on.

Like the shear force curve the ordinate value at the forward end (R = 100) should be zero. Corrections to make this so are performed using a parabola base correction. See Fig. 30, where YR is the correction for ordinate No. R.

On the ship under test, the error at the reading R = 100 was 135 tons ft., the maximum reading throughout the length of the vessel being of the order of 110000 tons ft. (Percentage error 0.12%).

The bending moment graph is a continuous polygon.

The Bending Moment table using Lloyd's method is on page 104, with the graph output on page 105 (in green). Page 104 (a) shows results using Biles Coffin method, and the appropriate graph is in red on page 105.

$$\frac{YR}{x^2} = \frac{B(100)}{L^2} \quad \therefore \quad YR = \frac{B(100) \cdot x^2}{L^2}$$

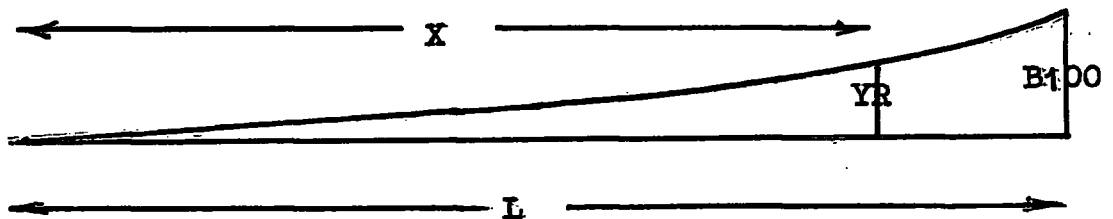


Fig. 30.

BENDING MOMENT CURVE ORDINATES.

(BILES COFFIN DISTRIBUTION)

ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT
0	0	1	-3	2	-44	3	-198
4	-595	5	-1520	6	-3340	7	-6294
8	-10002	9	-14025	10	-18369	11	-23024
12	-27895	13	-32850	14	-38010	15	-43633
16	-49767	17	-56300	18	-63135	19	-70012
20	-76625	21	-82959	22	-88902	23	-94273
24	-99040	25	-103149	26	-106551	27	-109220
28	-111132	29	-112259	30	-112589	31	-112330
32	-111492	33	-109852	34	-107386	35	-104099
36	-99986	37	-95043	38	-89266	39	-82650
40	-75185	41	-66865	42	-59425	43	-54652
44	-52592	45	-53217	46	-56727	47	-61580
48	-65857	49	-69384	50	-72159	51	-74193
52	-75494	53	-76068	54	-75923	55	-75060
56	-73479	57	-71324	58	-68594	59	-65147
60	-61000	61	-56165	62	-50649	63	-44458
64	-37598	65	-30071	66	-21887	67	-13127
68	-5605	69	-989	70	800	71	-228
72	-4269	73	-9629	74	-14404	75	-18580
76	-22142	77	-25092	78	-27436	79	-29168
80	-30289	81	-30810	82	-30784	83	-30444
84	-29789	85	-28641	86	-27031	87	-25006
88	-22618	89	-19928	90	-17000	91	-13813
92	-10358	93	-6977	94	-4312	95	-2497
96	-1279	97	-566	98	-211	99	-49
100	0						

Table 15(a)

BENDING MOMENT CURVE ORDINATES.

(LLOYD'S DISTRIBUTION)

ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT
0	0	1	-13	2	-78	3	-251
4	-638	5	-1502	6	-3213	7	-6017
8	-9540	9	-13350	10	-17459	11	-21861
12	-26468	13	-31151	14	-36034	15	-41381
16	-47241	17	-53505	18	-60078	19	-66702
20	-73074	21	-79177	22	-84904	23	-90071
24	-94649	25	-98583	26	-101825	27	-104348
28	-106127	29	-107134	30	-107357	31	-106999
32	-106071	33	-104346	34	-101799	35	-98431
36	-94236	37	-89210	38	-83351	39	-76654
40	-69110	41	-60714	42	-53199	43	-48354
44	-46223	45	-46778	46	-50219	47	-55004
48	-59211	49	-62669	50	-65373	51	-67335
52	-68562	53	-69059	54	-68833	55	-67888
56	-66219	57	-63974	58	-61148	59	-57600
60	-53346	61	-48398	62	-42763	63	-36446
64	-29452	65	-21784	66	-13451	67	-4534
68	3151	69	7928	70	9871	71	8982
72	5061	73	-207	74	-4920	75	-9072
76	-12651	77	-15663	78	-18118	79	-20012
80	-21348	81	-22137	82	-22434	83	-22470
84	-22243	85	-21572	86	-20483	87	-19018
88	-17224	89	-15153	90	-12859	91	-10308
92	-7480	93	-4702	94	-2601	95	-1295
96	-514	97	-146	98	-30	99	-3
100	0						

Table 15.

BENDING MOMENT CURVES

X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER = 27

HEIGHT OF Y-AXIS KF 29

HORIZONTAL SCALE OF GRAPH --- 1 CM = 20 FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:- 5000.0

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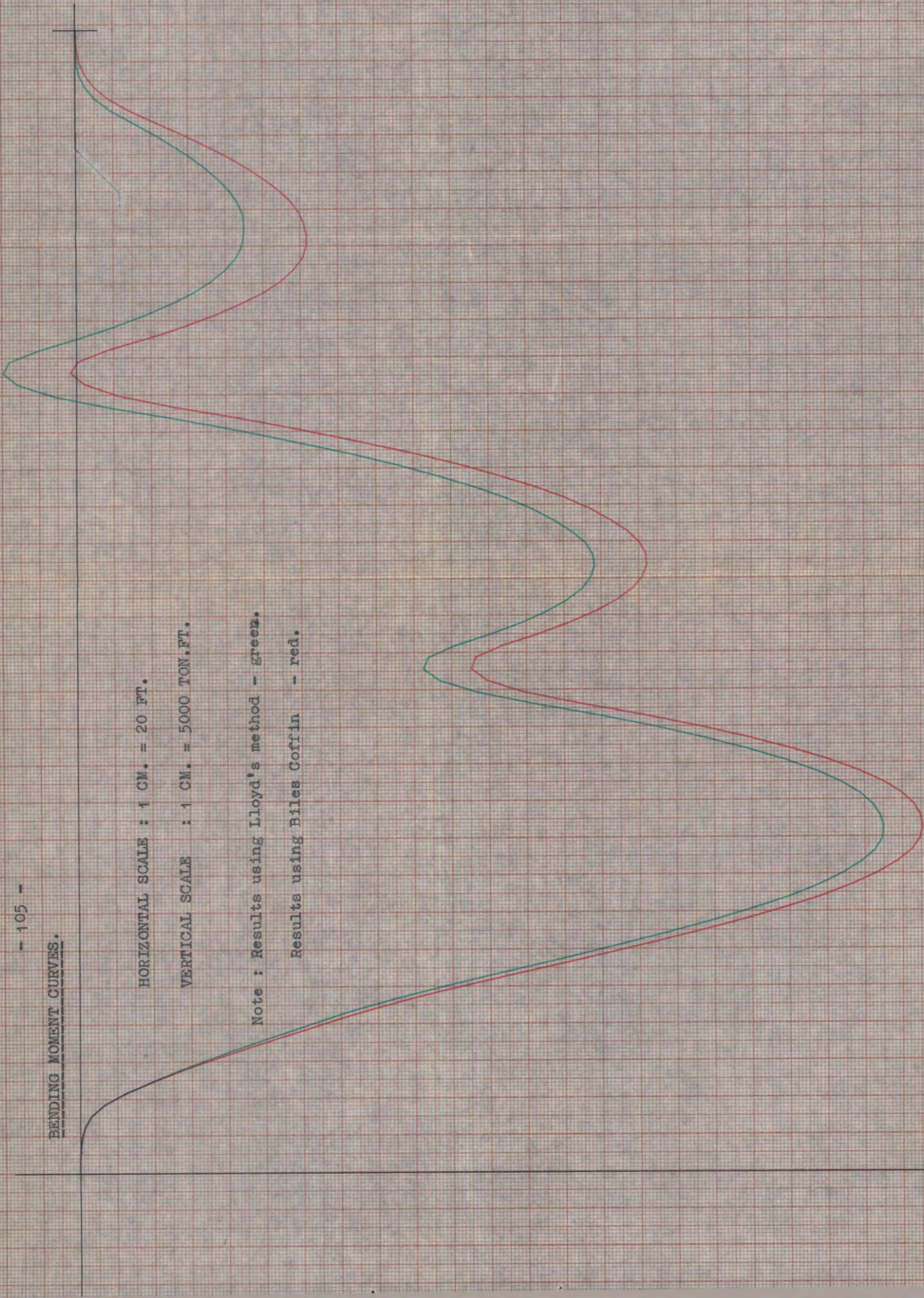
BENDING MOMENT CURVES.

HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 5000 TON.FT.

Note : Results using Lloyd's method - green.

Results using Biles Coffin - red.





## APPENDIX I

Set out below are details of the differences between the Sunderland Technical College programme and the programmes which are the subjects of the three reports mentioned on page vi of the Introduction.

### Considering the Glasgow Programme first:

The first obvious point of difference is that Glasgow offers FIVE methods of continuous weight distribution (including the two offered in this programme). Since the author understands (unofficially) that Lloyd's are in the process of determining other types of distribution in certain cases, and since Lloyd's must eventually pass judgement on the programme, there seems no point in including what may eventually have to be discarded. The understanding (by the author) is that in certain cases Biles Coffin may have to be used. I have, therefore, satisfied myself with providing the one coffin method, besides Lloyd's method.

The three extra methods in Glasgow's programme are:-

- (i) Cole or American Coffin diagram
- (ii) Robb Dry Cargo Ship
- (iii) Robb Tanker

Glasgow uses Coffin diagrams where the end ordinates are not zero. Biles end ordinates are taken to be  $0.6 \frac{W}{L_{OA}}$ . The alternative, used in the Sunderland programme, is to work with the weight between the



perpendiculars, and to fit triangular ends, for stern and bow sections.

Glasgow makes a point that comparison of the results using their different methods suggests that the error in bending-moment will not exceed  $0.01 \times W \times L_{OA}$ . In the case of Ship No. A842 considered in this thesis, this could be a matter of:

$$0.01 \times 4575 \times 580 = 26,535 \text{ ton ft.}$$

against a maximum value of about 110,000 ton ft. for Condition 1. A comparison of Biles Coffin results and Lloyd's results is made on page 105 of this thesis, in respect of Ship No. A842, where it will be seen that the difference is of the order of 5000 ton ft.

It would appear from Glasgow's write-up that with the one exception of the Robb Tanker method, end ordinates of the coffins are made equal (non zero). In our formula the ordinates at the perpendiculars are calculated, having been given the final position of L.C.G. (See page 32).

Also concerning local weights, Glasgow say they check that the C.G. of any item is within the centre 50% of the extent of the item, since trapezoidal distributions are assumed. In fact, looking at the formulae on page 12 of this thesis, it is seen that the C.G. must be within the centre  $33\frac{1}{3}\%$ . Our programme checks this and rejects the item if the condition is not fulfilled. It also prints out the offending

item, and WAITS for further action by the operator. If the error may be ignored, the programme may be allowed to carry on. Otherwise the tape is removed and corrected.

Data for the Glasgow programme is presented in a somewhat different form from that for our programme, and the formulae used for the local weights, for example, are in a completely different style. However, the number of output stations is, like this programme, 100.

One other difference is that immersed sectional areas are given (21 in number) for each loading condition being considered, whereas in our programme areas are calculated from the position of the waterline which is itself calculated from the mean draught and trim. Thirty one stations are considered in the Sunderland programme.

The three main differences in the two programmes are:

- (i) Glasgow required immersed sectional areas at 21 stations for every loading condition, whereas the Sunderland programme calculates and stores areas to every even waterline once only and calculates the required areas for any number of conditions.
- (ii) In the Lloyd's method for continuous weight distribution, Glasgow uses polynomial equations to represent the curved portions of the fore and aft bodies and the equations are expressed as a function of block coefficient and distances along the length from midship. Various other items of data are required such as L.C.G. position, and the computer

varies the lengths of the end curves to ensure correct L.C.G. position. In the Sunderland programme the yard provides the appropriate 'a' values for a known block coefficient at the load draught. This means one set of figures only. Everything else, such as the 'm' value, and the true and calculated positions of the L.C.G. of the continuous weight, together with the adjustment of the curve for correct L.C.G. and weight, is performed by the programme.

(iii) Glasgow do not include calculations in wave conditions.

There is no comparison of results using the two programmes; Glasgow do not say whether their programme satisfies Lloyd's Register of Shipping.

The Glasgow programme is written in KDF 9 Algol.

Comparison with the Vickers programme.

Vickers' programme performs the calculations for both still-water and for trochoidal wave forms.

Ordinates are calculated at intervals of L.B.P/100, as against the Sunderland programme using intervals of L.O.A/100. However, the three main differences in the programmes are:

- (i) Vickers split up the continuous weight into separate blocks of volume called portions, and do not use Biles Coffin or Lloyd's method. The number of such portions may be unlimited, and basic data for each portion, such as length and weight are read in. The lower part of some hull sections is defined by the use of buttock heights rather than half breadths. The Sunderland programme does not use this system - half breadths are used throughout.
- (ii) Complete hull definition data is read in, in the Vickers programme at the beginning, and this data, being stored, may be used for other programmes such as Hydrostatic and Bonjean calculations. The Sunderland programme stores the half-breadths for the station being considered and uses these to calculate immersed sectional areas to all even waterlines for that station, and stores this information for use in any number of loading conditions. Hydrostatics and Bonjean results can not be output.

One other small difference in the programme is that bossings are provided for in the Vickers programme, but not in the Sunderland programme.

(iii) For Bending Moments in wave forms, Vickers uses Trochoidal wave forms, whereas Sunderland uses Sine Wave.

There is no comparison of results using the two programmes (But see next section on B.S.R.A. notes).

Differences from the B.S.R.A. Programme.

The introduction to the B.S.R.A. notes says that the programme is a modification of that prepared by Vickers, (see last section). The modifications were made to satisfy Lloyds Register of Shipping, to insert several checks thought necessary, and to provide graphical output.

The programme is written in Mercury Autocode, as was the Vickers' programme.

Lloyds continuous weight distribution is performed by means of polynomials, as is the Glasgow programme, by feeding in the block coefficient and the station position along the ship length.

Equations used are of the form:-

$$A = Y_0 + (Y_1 - Y_0)X^2 + \sum_{M=0}^M \sum_{N=0}^N A_{mn} T_m(X) T_n(Z)$$

where  $T_m(X)$  and  $T_n(Z)$  are Chebysheve Polynomials,  $Y_0$  is a function of block coefficient,  $Y_1$  is constant,  $X$  and  $Z$  are functions of block coefficient and station. The coefficients  $A_{mn}$  are different for the foreand after bodies.

It is considered that the amount of effort involved in reading-off one set of 20 'a' values from Lloyd's tables does not warrant the introduction of such methods as the above into the programme (especially as they are read in once only, no matter how many conditions are to be programmed). Reference to page 39 of this thesis will clarify the simpler method used in the Sunderland programme.

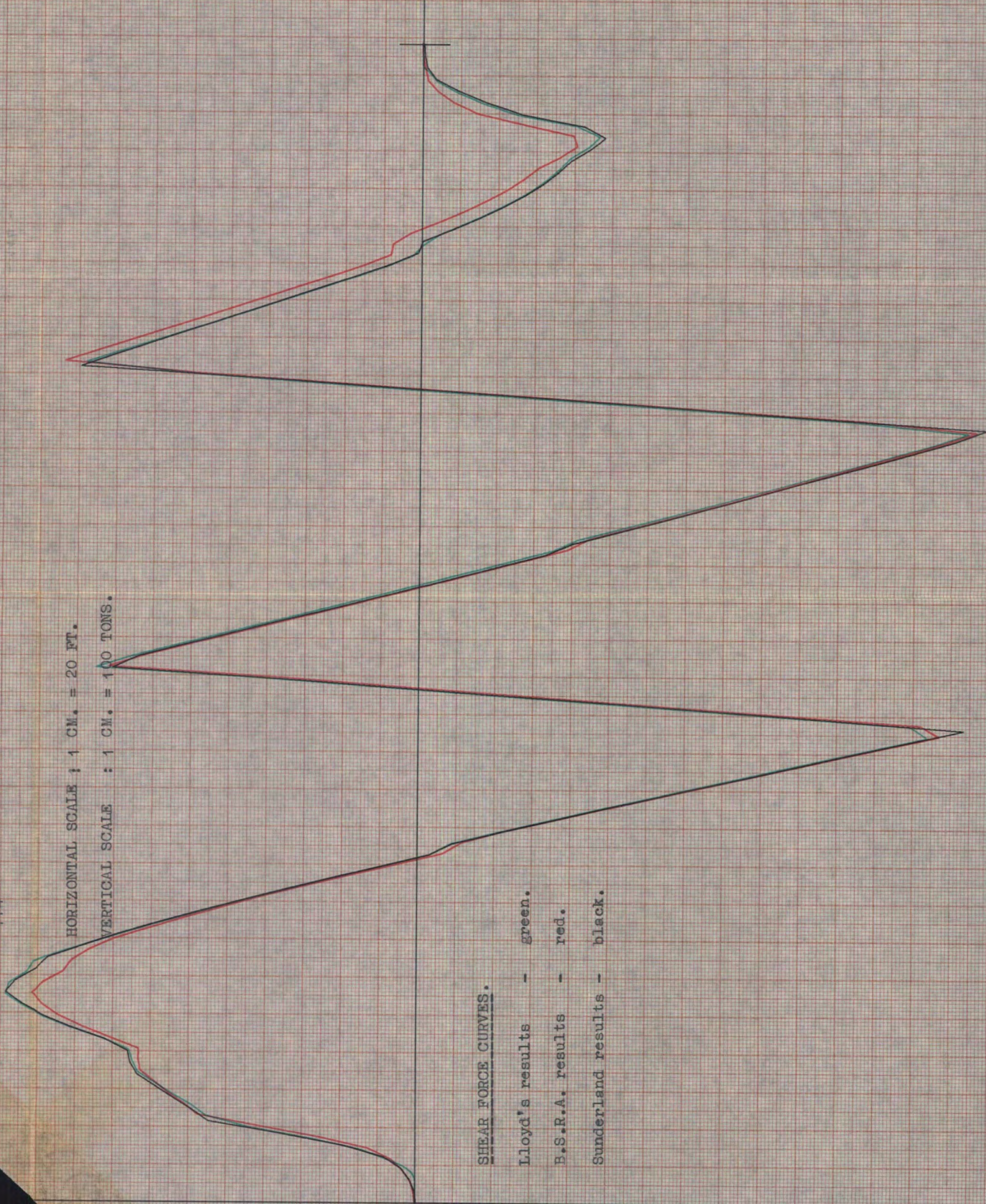
B.S.R.A. have provided the tabular outputs from their programme, as have Lloyd's, for purposes of comparison with those from the Sunderland programme.

Results from the three programmes may be compared from the graphs drawn on pages 114, 115. Page 114 shows the Shear Force curves and page 115 the Bending Moment curves. In both cases, Lloyd's results are in green, B.S.R.A's in red and Sunderland's in black.



HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 100 TONS.



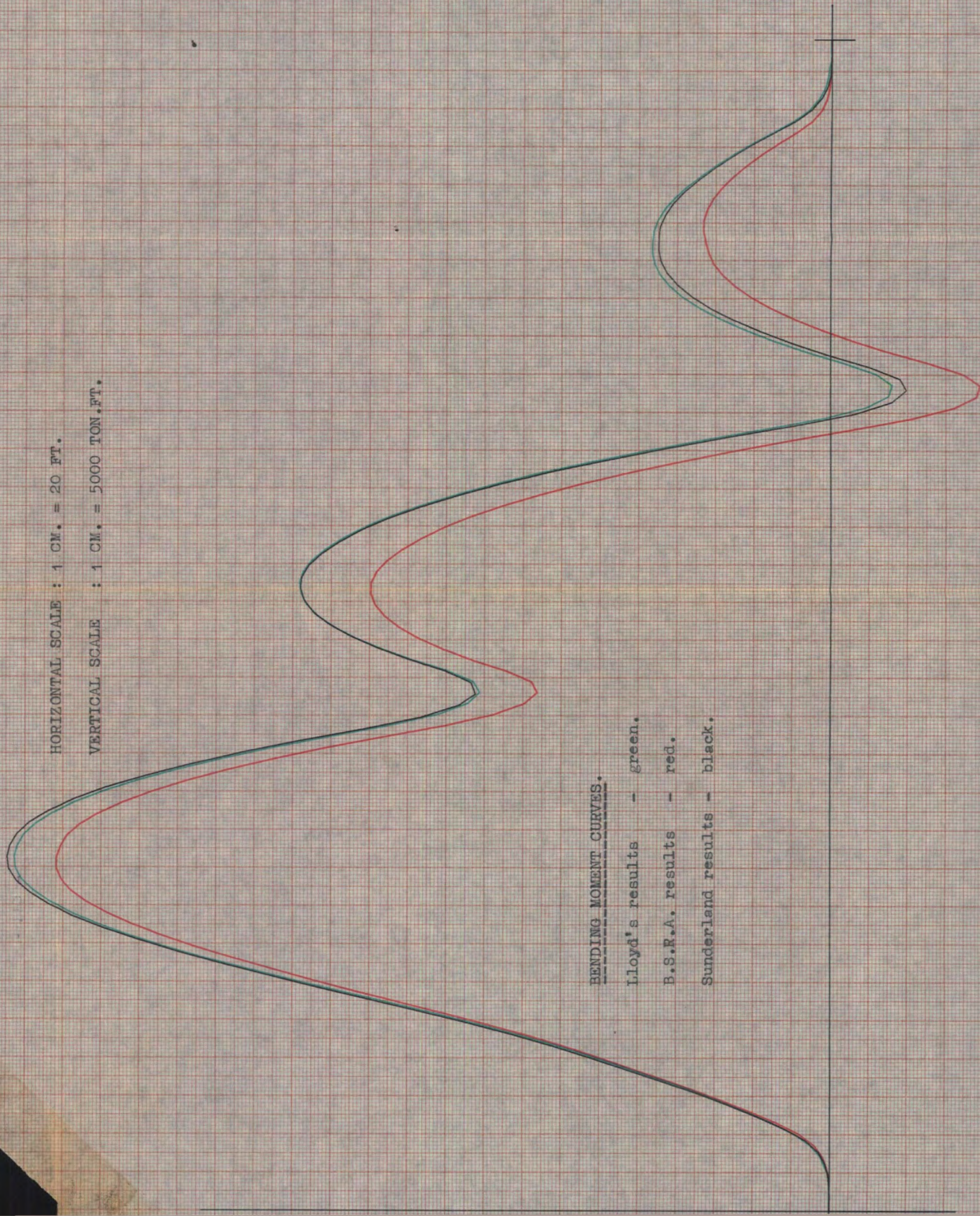
SHEAR FORCE CURVES.

Lloyd's results - green.  
 B.S.R.A. results - red.  
 Sunderland results - black.



HORIZONTAL SCALE : 1 CM. = 20 FT.

VERTICAL SCALE : 1 CM. = 5000 TON.FT.



BENDING MOMENT CURVES.

Lloyd's results - green.  
B.S.R.A. results - red.  
Sunderland results - black.



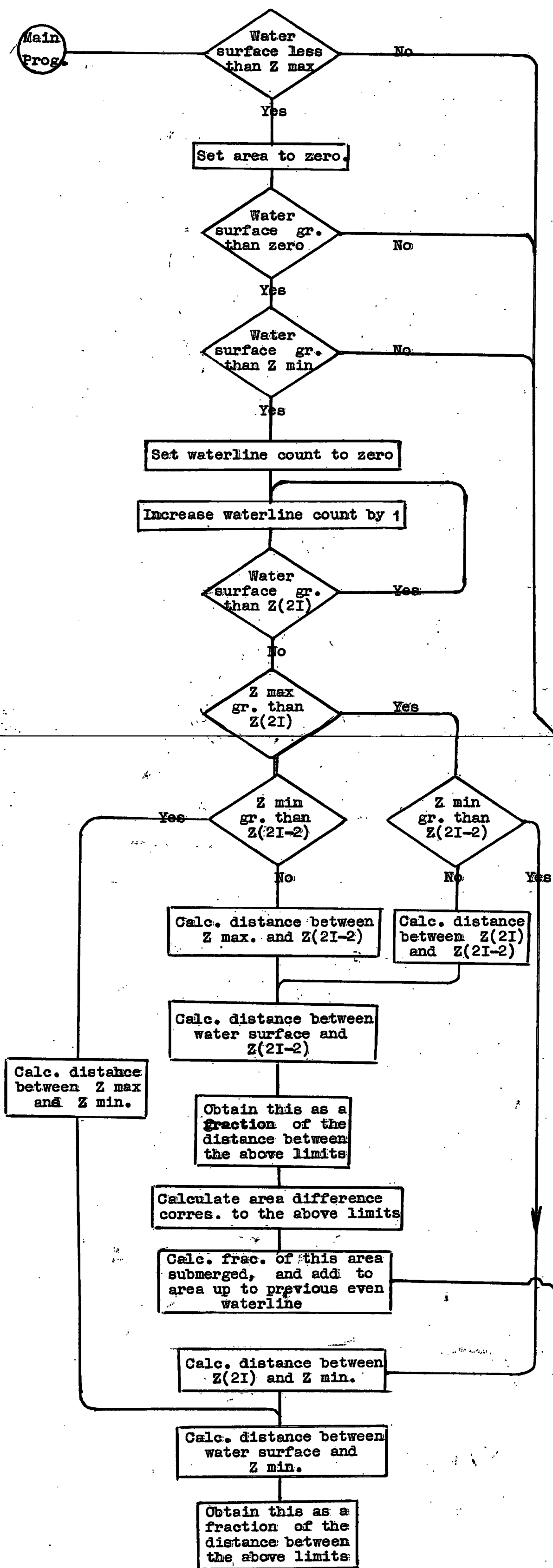
APPENDIX II

Page 117 shows the graphs drawn by the yard, from their own calculations, for ship No. A827. Superimposed on the graphs are the values produced by the 15 sections programme, mentioned on page iv of the introduction.

Since the latter half of 1966, the yard have accepted graphs drawn on the Benson Lehner graph plotter from tape produced by the Sunderland programme.

# FLOW CHART

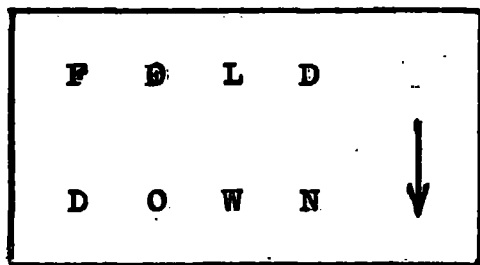
(Subr. 30, Programme p36)



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FLOW CHART

SUBROUTINE 30



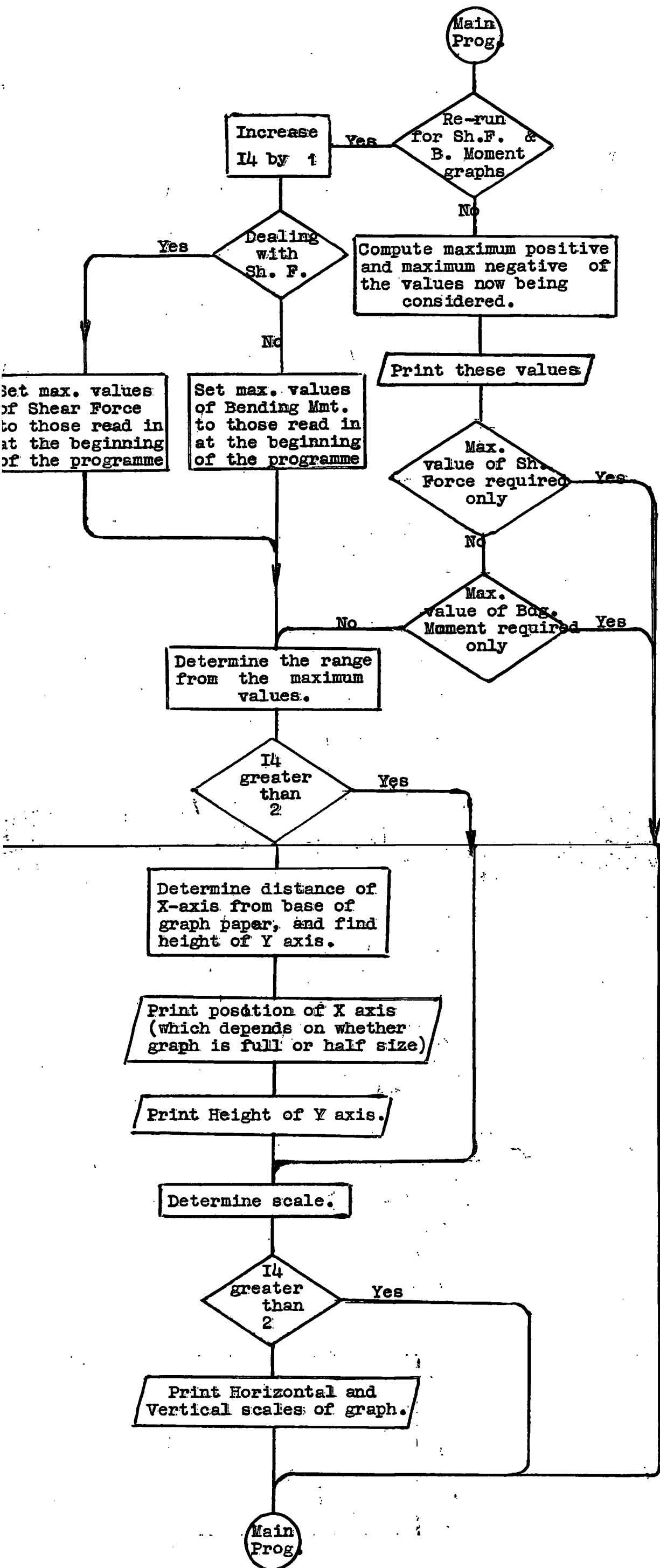
Main  
Prog

Check area submerged, either  
calculated, or previously set  
to max. or zero

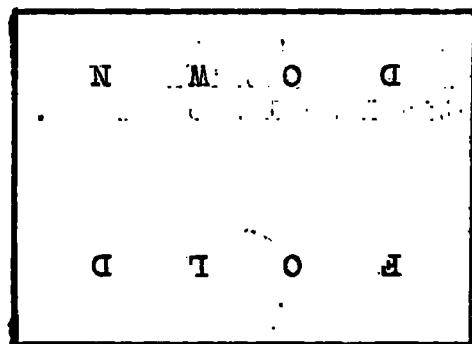
Calculate area submerged  
between 2 min and water  
surface

# FLOW CHART

(Subr. 86, Programme P 30)







---

SUBROUTINE 86

```

::      L O N G I T U D I N A L   S T R E N G T H
::      (JUNE 1967)
::      P R O G R A M M E   T O   C A L C U L A T E
::      B E N D I N G   M O M E N T S
::      (S T I L L - W A T E R / S I N E - W A V E)

```

```

SETS I(6)N(4)J(4)R(2)P(35)
SETV SC(27)T(6)W(65)L(15)B(100)X(100)M(7)Q(9)F(6)A(100)K(7)Y(100)
H(30)D(100)E(100)V(100)C(4)U(30)Z(112)O(774)G(52)
SETF INT FRAC TRIG GRAPH PLOT
SETR 143

```

```

1)READ I3::      IF CONDITIONS HAVE NOT BEEN RUN, PUT I3 = 0. IF ALL
I4=0::      CONDITIONS HAVE BEEN RUN, AND SHEAR FORCE CURVES FOR
JUMP IF I3=0@8::ALL CONDITIONS ARE TO BE REDRAWN ON SAME AXIS, TO THE
READ S25::      SAME SCALE (AND SIMILARLY FOR B.MMT. CURVES), I3 = 1
READ S26::      THESE TWO, MAX. +VE AND MAX. -VE SHEAR OVER ALL CONDS.
READ M6
READ M7::      " " " " " " " " " " B.MMT. " " " "

```

```

8)WAIT::FOR LIGHTSHIP LOCAL WEIGHTS TAPE
READ I1::      1 FOR BILES COFFIN, 0 FOR LLOYD'S METHOD
READ L::      LENGTH OVERALL
READ L1
READ L2
L3=L-L1
L3=L3-L2
L6=L/100
READ S22::      1 FOR FULL WIDTH GRAPH, 0.5 HALF WIDTH, 0 IF NO GRAPH
READ S27::      10, 20 OR 40 (FT. PER CM. HORIZONTAL SCALE), 0 IF NO GRAPH
JUMP IF S27=0@143
S24=100/S27
143)SUBR 124

```

```

S21=S1
VARY R=0:1:101
ER=YR
REPEAT R
T6=T5

```

```

WAIT::      FOR 2ND DATA TAPE

```

```

126)SUBR 124:: ENTRY POINT FOR ALL CONDITIONS AFTER THE FIRST
READ W31
READ K3

```

LINE::  
TITLE

LENGTH OVERALL :  
PRINT L,4:2  
TITLE FT

SUM OF LIGHTSHIP LOCAL WEIGHTS READ IN =  
PRINT S21,5:2  
TITLE TONS-

SUM OF EXTRA LOCAL WTS. FOR THIS CONDITION, READ IN =  
PRINT S1,5:2  
TITLE TONS

S=0  
VARY R=0:1:101  
YR=YR+ER  
S=S+YR  
REPEAT R  
S=S\*L6

TITLE

CALCULATED SUM OF DISTRIBUTED LOCAL WEIGHTS =  
PRINT S,5:2  
S3=S1+S21::ACTUAL SUM OF WEIGHTS INPUT  
T5=T6+T5  
Q6=W31\*35:: FOR MUCKLE'S METHOD BELOW  
JUMP IF I(1)=1@83:: FOR B C CONT. WT. DISTRIBUTION  
W32=W31-S3::CONTINUOUS WEIGHT - CHECKED EACH TIME ROUND  
K6=W31\*K3 -  
K6=K6-T5  
K6=K6/W32::LCG CONT.WT - CHECKED EACH TIME ROUND.  
JUMP IF P4%1@54  
VARY I=0:1:23  
READ A1::A VALUES FROM LLOYDS GRAPHS  
REPEAT I  
L4=L3/20  
L5=L4/3  
X1=L1  
X=0  
VARY I=2:1:20  
X1=X(I-1)+L4  
REPEAT I  
X22=X21+L2:: X - DISTANCES TO LLOYDS ORDINATES

```

Q=0::
VARY I=1:1:10
Q1=4*A(2I)
Q2=Q1+A(2I+1)
Q2=Q2+A(2I-1)
Q2=Q2*L5
Q=Q+Q2
REPEAT I
Q1=L1*A1
Q1=Q1/2
Q=Q+Q1
Q2=L2*A2I
Q2=Q2/2
Q=Q+Q2::VALUE UNDER WEIGHT CURVE IN TERMS OF 'M'.
M5=W32/Q
VARY I=0:1:23
A1=A1*M5::ACTUAL ORDINATE VALUES
REPEAT I

```

```

M4=0
VARY I=1:1:10
M1=4*A(2I)
M1=M1*X(2I)
M2=A(2I+1)*X(2I+1)
M3=A(2I-1)*X(2I-1)
M1=M1+M2
M1=M1+M3
M1=M1*L5
M4=M4+M1
REPEAT I

```

```

Q1=Q1*M5
M1=Q1*L1
M1=M1*0.6666666666
M4=M4+M1
Q2=Q2*M5
L7=L2*0.3333333333
L7=L7+L1
L7=L7+L3
M1=Q2*L7
M4=M4+M1

```

L8=M4/W32::L.C.G. OF CONTINUOUS WEIGHT CURVE (HORIZONTAL).  
L8=L8-K6::REQUIRED MOVEMENT OF L.C.G. TO BRING TO CORRECT POSITION.  
CHECK L8

```

M4=0::
VARY I=1:1:20
JUMP IF A(I+1)$AI@117
K=A(I+1)AI
M1=AI*AI
JUMP @118
117)K=AI-A(I+1)
M1=A(I+1)*A(I+1)
118)M1=M1*L4
M1=M1/2:

```

```

M2=K*L4
M2=M2/2:
K=K/3
JUMP IF A(I+1)$AI@49
K=K+AI
JUMP @50
49)K=K+A(I+1)
50)M2=M2*K
M4=M4+M1
M4=M4+M2:
REPEAT I

```

```

H=M4/W32::CENTRE OF AREA OF CONT. WT. CURVE (VERT).
CHECK H
M=L8/H::RATIO TO AFFECT ALL AI VALUES
CHECK M
VARY I=0:1:23
K=AI*M
XI=XI-K
REPEAT I

```

```

VARY R=0:1:101
DR=0
REPEAT R
N1=1
J1=100
I=0::THESE 3 FOR SUBR 58. I FOR EXTRA COUNT FOR XJ VALUES.

```

SUBR 58::INTERPOLATE 100 A VALUES - TO GIVE D VALUES

```

VARY R=0:1:100
J=R+1
S=DJ+DR
DR=S/2:
VR=DR
REPEAT R

```

LINE::  
54)TITLE TONS

CONTINUOUS WEIGHT TOTAL FOR LLOYD'S DISTRIBUTION =  
PRINT W32,5:2

TITLE TONS

CALCULATED 'M' - TONS/FT =  
PRINT M5,2:3

TITLE

CALCULATED L.C.G. OF CONTINUOUS WEIGHT =  
PRINT K6,3:2  
TITLE FT.

JUMP @84

83)JUMP IF P4%1@125

READ W33:: WEIGHT OF OVERHANG OF STERN

READ W34:: BOW

READ L4::LCG OF W33

READ L5:: W34

T1=W33\*L4

T2=W34\*L5

W32=W31-S

W32=W32-W33

W32=W32-W34

K=W31\*K3

K1=K

K=K-T5

K=K-T1

K=K-T2

K=K/W32

K=K-L1

L7=L3/2

K=K-L7

H=W32/L3

A1=W32\*K

A1=54\*A1

A1=A1/7

A1=A1/L3

A1=A1/L3

A2=H\*0.6

B=A2+A1

A=A2-A1

H1=1.2\*H

CHECK A

CHECK B

CHECK H1

```
J=0::
VJ=0
JUMP IF L1=0@140::TRANSOM STERN
H2=H1-A
L10=L1/L6
J=INT L10
H3=A/L1
CHECK J
CHECK H3
CYCLE I=0:1:J
C=STAND I
C=C*L6
VI=H3*C
REPEAT I
CYCLE I=1:1:J
R=I-1
S=VR+VI
VR=S/2
REPEAT I
140>L11=L3/3
R=J+1
C=STAND R
C=C*L6
C=C-L1
H3=H2/L11::RISE PER FT
CHECK H3
C1=C*H3::RISE TO R
VR=A+C1
S=A+VR
S=S*C
S=S/2
C=L6-C
S1=VJ+A
S1=S1/2
S1=S1*C
VJ=S+S1
VJ=VJ/L6
L12=L11+L1
L13=L12/L6
J2=INT L13
CHECK J2
J1=R+1
CYCLE I=J1:1:J2
R2=I-R
C=STAND R2
C=C*L6
C=C*H3
VI=VR+C
REPEAT I
CYCLE I=J1:1:J2
J=I-1
S=VI+VJ
VJ=S/2
REPEAT I
```



```
R=J2*:  
C=STAND J2  
C=C*L6  
C=L12-C  
S=VR+H1  
S=S/2  
S=S*C  
R1=R+1  
C=L6-C  
S1=C*H1  
S=S+S1  
VR=S/L6  
L13=2*L11  
L13=L13+L1  
L14=L13/L6  
J3=INT L14  
CHECK J3  
CYCLE I=R1:1:J3  
VI=H1  
REPEAT I  
H2=H1-B  
H3=H2/L11  
CHECK H3  
C=STAND J3  
C=C*L6  
C=L13-C  
S=H1*C  
C=L6-C  
C1=C*H3  
R=J3+1  
VR=H1-C1  
S1=H1+VR  
S1=S1*C  
S1=S1/2  
R=J3  
VR=S+S1  
VR=VR/L6  
R=J3+1  
L14=3*L11  
L14=L14+L1  
L15=L14/L6  
J4=INT L15  
R1=R+1  
CHECK J4  
CYCLE I=R1:1:J4  
R2=I-R  
C=STAND R2  
C=C*L6  
C=C*H3  
VI=VR-C  
REPEAT I
```

CYCLE I=R1:1:J4::

J=I-1

S=VJ+VI

VJ=S/2

REPEAT I

V100=0

JUMP IF J4=99@127

R=J4+1

H3=B/L2

CHECK H3

C1=H3\*L6

CYCLE I=99:-1:R

J=100-I

C=STAND J

C=C\*C1

VI=V100+C

REPEAT I

C=STAND J4

C=C\*L6

C=L14-C

R=J4

S=VR+B

S=S/2

S=S\*C

R=R+1

S1=VR+B

S1=S1/2

C=L6-C

S1=S1\*C

S=S+S1

R=J4

VR=S/L6

R=R+1

CYCLE I=R:1:99

J=R+1

S=VR+VJ

VI=S/2

REPEAT I

JUMP @125

127)R=J4

C=99\*L6

C=L14-C

S=V99+B

S=S\*C

S=S/2

C=L6-C

S1=B\*C

S1=S1/2

S=S+S1

V99=S/L6

125)W32=W31-S3

W32=W32-W33

W32=W32-W34

LINE::  
TITLE TONS

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PAGE 9

WEIGHT OF STERN OVERHANG

WEIGHT OF BOW OVERHANG

SPACES 8  
PRINT W33,5:2  
SPACES 15  
PRINT W34  
TITLE TONS

CONTINUOUS WEIGHT TOTAL (BILES COFFIN DISTRIBUTION) =  
PRINT W32

TITLE TONS

84)WAIT:: FOR TAPE 3 - CHOICE OF TABLES/GRAPHS FOR WEIGHT CURVES  
15=0  
16=0::FOR CONTROL IN SUBR 86

TITLE

NOTE: ORDINATES IN THE FOLLOWING OUTPUT ARE NUMBERED FROM THE  
EXTREME POINT OF STERN (ORDINATE NO. 0), TO THE POINT OF BOW  
(ORDINATE NO. 100), AND ARE UNIFORMLY SPACED.

READ P1::1 FOR L.WEIGHTS TABLE, 0 IF TABLE NOT REQD.  
JUMP IF P1=0@67  
VARY I=1:1:50  
OUTPUT 0  
REPEAT I  
TITLE

LOCAL WEIGHT ORDINATES (PROJECTED FORWARD).

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
------------	------------------	------------	------------------	------------	------------------	------------	------------------

VARY R=0:1:101  
K=STAND R  
K=K/4  
K=FRAC K  
JUMP UNLESS K=0@65  
LINE  
65)PRINT R  
PRINT YR,3:2  
REPEAT R

```
67)READ P2::
JUMP IF P2=0@87::GRAPH NOT REQD.-(1 IF GRAPH REQD.)
VARY R=0:1:101
BR=YR
REPEAT R
VARY I=1:1:25
OUTPUT 0
REPEAT I
```

TITLE

# LOCAL WEIGHT ORDINATES (PROJECTED FORWARD)

```
SUBR 86:: GRAPH SCALES
SUBR 110:: GRAPH OUTPUT
87)READ P1::1 FOR CONT. WEIGHT TABLE :0 IF OTHERWISE
JUMP IF P1=0@74
VARY I=1:1:50
OUTPUT 0
REPEAT I
```

TITLE

## CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
------------	------------------	------------	------------------	------------	------------------	------------	------------------

```
S=0
VARY R=0:1:101
K=STAND R
K=K/4
K=FRAC K
JUMP UNLESS K=0@27
LINE
27)PRINT R
PRINT VR.3:2
S=S+VR
REPEAT R
S=S*L6
LINE
CHECK S
```

```
74)READ P2::  
JUMP IF P2=0@73::0 IF GRAPH NOT REQD -(1 IF GRAPH REQD)  
VARY R=0:1:101.  
BR=VR  
REPEAT R  
VARY I=1:1:25  
OUTPUT 0  
REPEAT I
```

TITLE

CONTINUOUS WEIGHT CURVE ORDINATES (PROJECTED FORWARD).

-----

```
SUBR 86:: GRAPH SCALES  
SUBR 110:: GRAPH OUTPUT
```

```
73)S=0  
VARY R=0:1:101  
YR=YR+VR  
BR=YR::FOR SUBR 29 BELOW (LCG POSITION).  
S=S+YR  
REPEAT R  
S=S*L6  
LINE  
CHECK S  
W32=W31-S  
W3=MOD W32  
JUMP UNLESS W3*W31/1000@51  
TITLE
```

```
RESULTANT COMPUTED TOTAL WEIGHT =  
PRINT S,5:2  
TITLE TONS  
ERROR =  
W3=-W32  
PRINT W3,2:2  
TITLE TONS- % ERROR =  
W3=W3/W31  
W3=W3*100  
PRINT W3,2:2  
LINES 2  
VARY I=0:1:50  
OUTPUT 5  
REPEAT I::INDICATES BY OUTPUT OF $$$$$$$$ WHEN ERROR GR THAN 0.1%  
LINE
```

WAIT::IF ERROR IS ACCEPTABLE, PROGRAMME MAY BE CONTINUED.

51)SUBR 29:: TO OBTAIN PROVISIONAL L.C.G.

T2=T1-K3:  
T3=MOD T2:  
JUMP (UNLESS T3%K3/100@25  
TITLE

RESULTANT COMPUTED LCG POSITION =

PRINT T1,3:2:

TITLE FT FWD OF A.E.

ERROR =

PRINT T2,2:2:

TITLE FT % ERROR =

T3=T3/K3

T3=T3\*100

PRINT T3,2:2:

LINES 2

VARY I=0:1:50

OUTPUT 24

REPEAT I::INDICATES BY OUTPUT OF @@@@@@@@@@ WHEN ERROR GR THAN 1%

LINES 2

WAIT::IF ERROR IS ACCEPTABLE, PROGRAMME MAY BE CONTINUED.

25) L8=L/2:

K2=W31\*K3

K2=K2-T

K2=K2/W32:

K1=K2:

A=W32/L

A=A/L

JUMP IF K2\$L8@20

K2=L-K2

20) K2=K2\*6

K2=K2-L

K2=K2-L

A=A\*K2:

B=2\*W32:

B=B/L

B=B-A

JUMP IF K1\$L8@23

F=A

A=B

B=F

23) D=B

B=D-A

CHECK D

CHECK A

CHECK B

F=B/100

VARY R=0:1:101

S=STAND R

BR=S\*F

BR=D-BR

REPEAT R

VARY R=0:1:100::  
J=R+1  
S=BR+BJ  
S=S/2  
BR=S  
REPEAT R

READ P1::1 FOR WEIGHT CURVE ORDINATES: 0 IF OTHERWISE  
JUMP IF P1=0@75  
VARY I=1:1:50  
OUTPUT 0  
REPEAT I

TITLE

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT	ORD NO.	WEIGHT TON/FT
------------	------------------	------------	------------------	------------	------------------	------------	------------------

75)S=0  
VARY R=0:1:100  
YR=YR+BR  
JUMP IF P1=0@76  
K=STAND R  
K=K/4  
K=RAC K  
JUMP UNLESS K=0@28  
LINE  
28)PRINT R  
PRINT YR.3:2  
76)BR=YR::FOR GRAPH OUTPUT AND FOR SUBR 29 (FOR LCG POSITION).  
S=S+YR  
REPEAT R  
S=S\*L6

SUBR 29::TO OBTAIN LCG

VARY I=1:1:25  
OUTPUT 0  
REPEAT I



READ P2::

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TITLE

WEIGHT

L.C.G. FWD. A.E.

SPACES 4

PRINT S,6:2

SPACES 9

PRINT T1,3:2

JUMP IF P2=0@90::0 IF GRAPH NOT REQD.

VARY I=1:1:25

OUTPUT 0

REPEAT I

TITLE

TOTAL WEIGHT CURVE ORDINATES (PROJECTED FORWARD)

SUBR 86:: GRAPH SCALES

SUBR 110::GRAPH OUTPUT

90)READ S17::MEAN DRAUGHT

READ M2::MCT.1

READ L10::L.C.B.FWD.OF A.E.

READ L11::L.C.F.FWD.OF A.E.

READ S16::WAVE HEIGHT (CREST TO TROUGH)

READ L9:: WAVELENGTH - DATA SHEET 0 IF STILL WATER

READ P3:: 1 IF SAGGING, 0 IF HOGGING OR STILL WATER

READ S18: FT.FROM STERN WHERE CREST OR TROUGH OF WAVE FALLS

X1=L3/10

S1=L1/4

S2=S1

CYCLE I=3,4,12,13

S1=0.125\*X1

REPEAT I

S5=0.25\*X1

S11=S5

S6=0.5\*X1

S10=0.5\*X1

```
VARY I=7:1:3:
SI=X1
REPEAT I
S14=L2/4
S15=S14
X=0
CHECK X
VARY J=1:1:15
X(2J-1)=X(2J-2)+SJ
X(2J)=X(2J-1)+SJ
CHECK X(2J-1)
CHECK X(2J)
REPEAT J::X - VALUES TO 31 STATION POSITIONS.
```

```
L12=L10-K3:: (LCB-LCG)
B2=W31*L12:
B3=B2/M2:: TRIMMING MOMENT / MCT1 = TRIM IN INCHES
B3=B3/12:: TRIM IN FEET
F1=B3/L3:: TRIM IN FT PER FT LENGTH
F6=F1*L11:: TRIM IN FT OVER DISTANCE OF LCF FROM AE.
F6=S17+F6:: DRAUGHT AT STERN - STILL WATER.
```

WAIT:: FOR TAPE 4 - BONJEAN DATA.

JUMP IF P4%1@19

```
123)READ H:: WATERLINE SPACING.
READ Q1:: FOR CHOICE OF 1/8THS OR 1/4S
READ N1
READ N2
N=N1+N2:
JUMP IF Q1=0.125@10
N=N+3
N3=2*N
Z=0
H1=H/4
H2=H/4
H3=H/2:
VARY I=4:1:N1
H1=H
REPEAT I
N4=N1+4
JUMP @16
10)N=N+4
N3=2*N
Z=0
H1=H/8
H2=H/8
H3=H/4
H4=H/2:
```

```

VARY I=5:1:N1::
HI=H
REPEAT I
N4=N1+5
16) JUMP IF N2=0@6
VARY I=N4:1:N2
HI=H/2
REPEAT I
6) VARY I=1:1:N
Z(2I-1)=Z(2I-2)+HI
Z(2I)=Z(2I-1)+HI
CHECK Z(2I-1)
CHECK Z(2I)
REPEAT I
VARY J=0:1:31
READ S19:: SECTION NUMBER
CHECK S19
READ P(J+5):: 0 IF NO READINGS IN COLUMN, 1 OTHERWISE
JUMP IF P(J+5)=0@62
READ Z(51+J):: Z MIN
READ Z(82+J):: Z MAX.
CYCLE I=0:1:N3
READ G1
REPEAT I:: ALF-WIDTHS.
READ G52:: Y AT Z MAX.
I=0
O(25J+1)=0
CHECK I
CHECK O(25J+1)
JUMP IF Z(51+J)=0@33
READ G51
31) I=I+1
M=Z(51+J)-Z(2I)
M=MOD M
JUMP IF M$0.0001@42:: ENSURES ZERO RESULT IF Z MIN SHOULD 'EQUAL'
JUMP IF Z(51+J)$Z(2I)@32:: Z(2I), IN FL.PT. MODE.
O(25J+1)=O(25J)
CHECK I
CHECK O(25J+1)
JUMP @31
42) Z(51+J)=Z(2I)
32) T=Z(2I)-Z(51+J)
T=T/3
T1=4*G51
T2=T1+G(2I)
S20=T2*T
R=I-1
O(25J+1)=O(25J+R)+S20
CHECK I
CHECK O(25J+1)
JUMP IF Z(82+J)$Z(2I+2)@120

```

```

33>I=I+1::
T=HI/1.5
T1=4*G(2I-1)
T2=T1+G(2I-2)
T2=T2+G(2I)
T2=T2*T
R=I-1
O(25J+I)=O(25J+R)+T2
CHECK I
CHECK O(25J+I)
JUMP IF Z(82+J)%Z(2I+2)@33
120>T=Z(82+J)-Z(2I)
T1=G(2I)+G52
T1=T1*T
R=I
I=I+1
O(25J+I)=O(25J+R)+T1
CHECK I
CHECK O(25J+I)
W(35+J)=O(25J+I)::MAX. AREA
62>REPEAT J

```

```

19>VARY J=0:1:31
JUMP IF P(J+5)=0@38
I=0
HJ=0
JUMP IF L9=0@39
C=XJ-S18
C=2*C
C=C/L9
C=COS C
JUMP IF P3=1@26
C=-C
26>HJ=S16/2
HJ=HJ*C
39>B=F1*XJ
B=-B+F6
HJ=HJ+B
CHECK HJ::

```

WAVE HEIGHT ABOVE KEEL

UJ=W(35+J)::  
SUBR 30  
WJ=UJ

JUMP IF L9=0@41  
JUMP IF P3=0@71

HJ=HJ+4  
JUMP @72:  
71)HJ=HJ-4  
72)UJ=W(35+J)

SUBR 30

JUMP @41  
38)WJ=0  
UJ=0  
CHECK WJ  
CHECK UJ  
41)REPEAT J

JUMP IF L9=0@56  
M=0  
M1=0  
M3=0  
M4=0  
Q1=0  
Q3=0

VARY I=1:1:15  
T=SI/3  
T1=4\*W(2I-1)  
T2=T1+W(2I)  
T2=T2+W(2I-2)  
T2=T2\*T  
Q1=Q1+T2

T1=T1\*X(2I-1)  
T2=W(2I)\*X(2I)  
T3=W(2I-2)\*X(2I-2)  
T4=T1+T2  
T4=T4+T3  
T4=T4\*T  
M=M+T4

$T1 = T1 * X(2 \text{ I} - 1) ::$   
 $T2 = T2 * X(2 \text{ I})$   
 $T3 = T3 * X(2 \text{ I} - 2)$   
 $T4 = T1 + T2$   
 $T4 = T4 + T3$   
 $T4 = T4 * T$   
 $M3 = M3 + T4$

$T1 = 4 * U(2 \text{ I} - 1)$   
 $T2 = T1 + U(2 \text{ I})$   
 $T2 = T2 + U(2 \text{ I} - 2)$   
 $T2 = T2 * T$   
 $Q3 = Q3 + T2$

$T1 = T1 * X(2 \text{ I} - 1)$   
 $T2 = U(2 \text{ I}) * X(2 \text{ I})$   
 $T3 = U(2 \text{ I} - 2) * X(2 \text{ I} - 2)$   
 $T4 = T1 + T2$   
 $T4 = T4 + T3$   
 $T4 = T4 * T$   
 $M1 = M1 + T4$

$T1 = T1 * X(2 \text{ I} - 1)$   
 $T2 = T2 * X(2 \text{ I})$   
 $T3 = T3 * X(2 \text{ I} - 2)$   
 $T4 = T1 + T2$   
 $T4 = T4 + T3$   
 $T4 = T4 * T$   
 $M4 = M4 + T4$

REPEAT 1

$Q3 = Q3 - Q1$   
 $Q3 = Q3 / 4$   
 $Q2 = M1 - M$   
 $Q2 = Q2 / 4$   
 $Q4 = Q2 / L$   
 $Q5 = M4 - M3$   
 $Q5 = Q5 / 4$   
 $Q5 = Q5 / L$

$Q7 = Q6 * K3$   
 $Q8 = Q6 - Q1$   
 $Q9 = Q7 - M$   
 $F2 = Q4 * Q2$   
 $F3 = Q8 * Q2$   
 $F4 = Q3 * Q5$   
 $F5 = Q9 * Q3$   
 $F2 = F2 - F4$   
 $F3 = F3 - F5$   
 $B = F3 / F2$   
 $F1 = Q4 * B$   
 $Q8 = Q8 - F1$   
 $A = Q8 / Q3$

CHECK A::  
CHECK B  
VARY J=0:1:31  
S=XJ\*B  
S=S/L  
S=S+A  
UJ=UJ-WJ  
UJ=UJ/4  
S=S\*UJ  
WJ=WJ+S  
REPEAT J

56) VARY J=0:1:31  
AJ=WJ/35  
REPEAT J

VARY R=0:1:101  
DR=0  
REPEAT R

I=0::EXTRA COUNT FOR XJ IN SUBR 58  
JUMP IF A%0@131  
N=0  
VARY R=1:1:10  
JUMP IF N%0@132  
S=AR-A(R-1)  
JUMP IF S=0@132  
N=R  
I=N-1  
132) REPEAT R  
131) J=30  
JUMP IF A30%0@133  
VARY R=29:-1:10  
JUMP IF J\$30@134  
S=AR-A(R+1)  
JUMP IF S=0@134  
J=R  
134) REPEAT R

133) X=XI  
X1=X(I+1)  
X2=X(I+2)  
A=A1  
A1=A(I+1)  
A2=A(I+2)

S=XI/L6  
N1=INT S  
N1=N1+1  
S=XJ/L6  
J=INT S  
J1=J+1



SUBR 58:: 100 D VALUES

PAGE 21:

```

I=0
138) S=0
VARY R=1:1:100
M1=DR+D(R-1)
M1=M1/2
S=S+M1
REPEAT R
S=S*L6
CHECK S
JUMP IF I=1@139
W32=W31-S
N2=J1-N1
CHECK N2
K=STAND N2
K=W32/K
K=K/L6

```

```

VARY R=N1:1:N2
DR=DR+K
REPEAT R

```

```

I=I+1
JUMP @138

```

```

139) VARY I=0:1:100
M1=D(I+1)-D(I)
BI=M1/2
REPEAT I

```

SUBR 29

M4=0

```

VARY I=0:1:100
JUMP IF D(I+1)$DI@12
K=D(I+1)-DI
M1=DI*DI
JUMP @142

```

```

12) K=DI-D(I+1)
M1=D(I+1)*D(I+1)
142) M1=M1*L6
M1=M1/2
M2=K*L6
M2=M2/2
K=K/3
JUMP IF D(I+1)$DI@141

```

```
K=K+D1::  
JUMP @135  
141)K=K+D(1+1)  
135)M2=M2*K  
M4=M4+M1  
M4=M4+M2  
REPEAT I::VERTICAL MOMENTS
```

```
VARY R=0:1:101  
AR=DR  
DR=0  
REPEAT R
```

```
H=M4/S::CENTRE OF AREA OF BUOYANCY CURVE (VERT).  
CHECK H
```

```
L8=T1-K3  
M=L8/H::RATIO TO AFFECT ALL AI VALUES  
CHECK M
```

```
X=0  
VARY J=1:1:50  
X(2J-1)=X(2J-2)+L6  
X(2J)=X(2J-1)+L6  
REPEAT J
```

```
VARY I=0:1:101  
S=A1*M  
XI=XI-S  
REPEAT I
```

```
I=N1-1  
X=XI  
X1=X(I+1)  
X2=X(I+2)  
A=A1  
A2=A(I+1)
```

```
SUBR 58
```

```
VARY R=0:1:100  
J=R+1  
S=DJ+DR  
DR=S/2  
REPEAT R
```

WAIT::FOR TAPE 5 - CHOICE OF REMAINING TABLES/GRAPHS.. PAGE 23

READ P1:: 1 FOR BUOYANCY TABLE REQD., - 0 OTHERWISE.  
JUMP IF P1=0@77

VARY I=1:1:50  
OUTPUT 0  
REPEAT I

TITLE

BUOYANCY CURVE ORDINATES (PROJECTED FORWARD).

ORD NO.	BUOY TON/FT	ORD NO.	BUOY TON/FT	ORD NO.	BUOY TON/FT	ORD NO.	BUOY TON/FT
------------	----------------	------------	----------------	------------	----------------	------------	----------------

77)S=0  
VARY R=0:1:100  
JUMP IF P1=0@119  
K1=STAND R  
K1=K1/4  
K1=FRAC K1  
JUMP UNLESS K1=0@61  
LINE  
61)PRINT R  
119)JUMP IF DR\$0@44  
JUMP @43  
44)DR=0  
43)JUMP IF P1=0@78  
PRINT DR,3:2:  
78)BR=DR::FOR GRAPH  
S=S+DR  
REPEAT R

S=S\*L6  
CHECK S  
SUBR 29:: TO OBTAIN LCB.  
VARY I=1:1:25  
OUTPUT 0  
REPEAT I

LINE::  
TITLE

PAGE 24

DISPLACEMENT

L.C.B.  
FWD.A.E.

SPACES 3  
PRINT S,7:2  
SPACES 7  
PRINT T1,4:2  
LINE  
READ P2  
JUMP IF P2=0091  
VARY I=1:1:25  
OUTPUT 0  
REPEAT I  
TITLE

BUOYANCY CURVES ORDINATES (PROJECTED FORWARD).

---

SUBR 86:: GRAPH SCALES  
SUBR 110:: GRAPH OUTPUT

91)VARY R=0:1:101  
YR=DR-YR  
BR=YR  
REPEAT R

READ P1:: 1 IF LOAD CURVE TABLE REQD. - 0 OTHERWISE.  
JUMP IF P1=0079  
VARY I=1:1:50  
OUTPUT 0  
REPEAT I  
TITLE

LOAD CURVE ORDINATES (PROJECTED FORWARD)

ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT	ORD NO.	LOAD TON/FT
------------	----------------	------------	----------------	------------	----------------	------------	----------------

```
VARY R=0:1:101::
K1=STAND R
K1=K1/4
K1=FRAC K1
JUMP UNLESS K1=0@17
LINE
17)PRINT R
PRINT YR,3:2:
REPEAT R
```

```
79)READ P2:
JUMP IF P2=0@112:
```

```
VARY I=1:1:25
OUTPUT 0
REPEAT I
```

TITLE

LOAD CURVE ORDINATES (PROJECTED FORWARD)

---

```
SUBR 86:: GRAPH SCALES
SUBR 110:: GRAPH OUTPUT
112)D=0
VARY J=0:1:100
R=J+1
A=YJ*L6
DR=DJ+A
REPEAT J
CHECK D100
F=D100/100
VARY J=0:1:101
JUMP IF J=0@21:
K1=STAND J
YJ=K1*F
YJ=DJ-YJ
JUMP @113
21)Y=0
113)BJ=YJ
REPEAT J
```

```
READ P1::1 IF SHEAR FORCE TABLE REQD.- 0 OTHERWISE
JUMP IF P1=0@92:
VARY I=1:1:50
OUTPUT 0
REPEAT I
```

LINE::

PAGE 26

TITLE

SHEAR FORCE CURVE ORDINATES.

ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS	ORD NO.	S.F. TONS
VARY J=0:1:101							
K1=STAND J							
K1=K1/4							
K1=FRAC K1							
JUMP UNLESS K1=0@40							
LINE							
40)PRINT J							
PRINT YJ,5:0							
REPEAT J							

92)READ P2:  
 READ 15:: FOR CONTROL IN SUBR 86 - (FIRST SET TO ZERO ON  
 JUMP IF P2=1@114:: PAGE 9, FOR ALL PREVIOUS CURVES.  
 JUMP IF 15=0@15  
 114)VARY I=1:1:25  
 OUTPUT 0  
 REPEAT I  
 TITLE

SHEAR FORCE CURVE

-----  
 SUBR 86:: GRAPH SCALES  
 JUMP IF P2=0@15  
 SUBR 109:: GRAPH OUTPUT

15)X=0  
 VARY J=1:1:50  
 X(2J-1)=X(2J-2)+L6  
 X(2J)=X(2J-1)+L6  
 REPEAT J

B=0

```
VARY J=0:1:100::
R=J+1
A=YR+YJ
A=A*L6
A=A/2
BR=BJ+A
REPEAT J
CHECK B100
VARY J=0:1:101
JUMP IF J=0@55
K1=STAND J
YJ=L*L
YJ=B100/YJ
K2=XJ*XJ
YJ=YJ*K2
BJ=BJ-YJ
JUMP @115
55)B=0
115)REPEAT J
```

```
READ P1::1 FOR BENDING MOMENTS TABLE -0 OTHERWISE
JUMP IF P1=0@68
VARY I=1:1:50
OUTPUT 0
REPEAT I
```

TITLE

BENDING MOMENT CURVE ORDINATES.

ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT	ORD NO.	B.M. TON FT
------------	----------------	------------	----------------	------------	----------------	------------	----------------

```
VARY J=0:1:101
K1=STAND J
K7K1/4
K1=FRAC K1
JUMP UNLESS K1=0@66
LINE
66)PRINT J
PRINT BJ,6:0
REPEAT J
```



68)I5=0::

READ P2

READ I6:: FOR CONTROL IN SUBR 86 - PREVIOUSLY SET TO ZERO ON

JUMP IF P2=1@93::GRAPH REQUIRED ON PAGE 9.

JUMP IF I6=0@121

93)VARY I=1:1:25

OUTPUT 0

REPEAT I

TITLE

BENDING MOMENT CURVES

SUBR 86:: GRAPH SCALES

JUMP IF P2=0@121

SUBR 109:: GRAPH OUTPUT

121)STOP:: END OF PROGRAMME.

29)X=L6/2

T=0

VARY R=0:1:100

M=BR\*L6

M=M\*X

T=T+M

X=X+L6

REPEAT R

T1=T/S

EXIT

```
58)R=N1::
S=STAND N1
S=S*L6
N=2+1
85)Q6=S-X0
Q7=S-X1
Q8=S-X2
F0=Q6*Q7
F1=Q6*Q8
F2=Q7*Q8
Q=X2-X0
Q1=X2-X1
Q2=X1-X0
Q3=X1-X2
Q4=X0-X1
Q5=X0-X2
Q6=Q*Q1
Q7=Q2*Q3
Q8=Q4*Q5
F0=F0/Q6
F1=F1/Q7
F2=F2/Q8
F0=F0*A2
F1=F1*A1
F2=F2*A0
F=F+F1
F=F+F2
DR=F
CHECK DR
CHECK R
S=S+L6
R=R+1
JUMP IF R=J1082
JUMP IF R%50@60
59)JUMP IF S%X1@81
60)JUMP IF S%X2@81
JUMP @85
81)X0=X1
X1=X2
A0=A1
A1=A2
N=N+1
X2=XN
A2=AN
JUMP IF R%50@60
JUMP @59
82)EXIT
```

```
86)JUMP IF 13%0@48::
K4=0
K5=0
VARY R=1:1:100
JUMP UNLESS BR%K5@88
K5=BR
88)JUMP UNLESS BR$K4@89
K4=BR
89)REPEAT R
TITLE
```

```
MAXIMUM POSITIVE VALUE =
PRINT K5.7:2
TITLE
```

```
MAXIMUM NEGATIVE VALUE =
PRINT K4
```

```
JUMP IF 15=1@45
```

```
JUMP IF 16=1@45
```

```
JUMP @57
```

```
48)I4=I4+1
```

```
JUMP IF 15=0@24
```

```
K5=S25
```

```
K4=S26
```

```
JUMP @57
```

```
24)K5=M6
```

```
K4=M7
```

```
57)K5=K5-K4::RANGE
```

```
JUMP IF 14%2@53::AVOIDS RE-PRINTING THE FOLLOWING TITLES
```

```
K4=-K4/K5::FRACTION OF RANGE
```

```
K7=1-K4
```

```
K4=K4*30
```

```
K4=K4*S22::DIST(IN CMS) OF X-AXIS FROM BASE OF GRAPH PAGE
```

```
K7=K7*30
```

```
K7=K7*S22
```

```
K7=K7+K4::HEIGHT OF Y-AXIS
```

```
TITLE
```

```
X-AXIS DISTANCE (CMS) FROM BASE OF GRAPH PAPER =
```

```
JUMP IF S22=1@136::IF S22=0.5 ALL X-AXES MAY BE CENTRAL.
```

```
TITLE 16
```

```
JUMP @137
```

```
136)R=INT K4
```

```
PRINT R
```

```
137)TITLE
```

```
HEIGHT OF Y-AXIS =
```

```
R=INT K7
```

```
PRINT R
```

53) JUMP UNLESS K5%15@94::  
 JUMP UNLESS K5%30@95  
 JUMP UNLESS K5%150@96  
 JUMP UNLESS K5%300@97  
 JUMP UNLESS K5%600@98  
 JUMP UNLESS K5%1500@99  
 JUMP UNLESS K5%3000@100  
 JUMP UNLESS K5%6000@101  
 JUMP UNLESS K5%15000@102  
 JUMP UNLESS K5%30000@103  
 JUMP UNLESS K5%60000@104  
 JUMP UNLESS K5%150000@105  
 JUMP UNLESS K5%300000@106  
 JUMP UNLESS K5%600000@107

JUMP @108

94) S=200

JUMP @116

95) S=100

JUMP @116

96) S=20

JUMP @116

97) S=10

JUMP @116

98) S=5

JUMP @116

99) S=2

JUMP @116

100) S=1

JUMP @116

101) S=0.5

JUMP @116

102) S=0.2

JUMP @116

103) S=0.1

JUMP @116

104) S=6.05

JUMP @116

105) S=0.02

JUMP @116

106) S=0.01

JUMP @116

107) S=0.005

JUMP @116

108) S=0.002

116) S=S\*S22:: ADJUSTS FOR 30 CM. OR 15 CM. WIDE PAGE

JUMP IF 14%2@80:: AVOID RE-PRINTING THE FOLLOWING TITLES.  
 TITLE

HORIZONTAL SCALE OF GRAPH --- 1 CM =

PRINT S27.2

TITLE FT

VERTICAL SCALE OF GRAPH --- UNITS/CM:-

S1=100/S

PRINT S1,5:1

TITLE

```
80) VARY R=0:1:200:
  OUTPUT 0
  REPEAT R
45) EXIT
```

```
109) C3=0
  C4=0
  C1=0
  C2=0
  F=GRAPH C1,C2:
  CYCLE R=0:1:99
  C1=L6*S24
  C1=C1+C4
  C2=B(R+1)-BR
  C2=C2*S
  C2=C2+C3
  F=GRAPH C1,C2:
  C4=C1
  C3=C2:
  REPEAT R
  VARY R=1:1:200
  OUTPUT 0
  REPEAT R
  EXIT
```

```
110) C1=0
  C2=0
  F=GRAPH C1,C2:
  C2=B*S
  F=GRAPH C1,C2:
  C1=L6*S24
  F=GRAPH C1,C2:
  C4=C1
  C3=C2:
  VARY R=1:1:100
  C2=BR-B(R-1)
  C2=C2*S
  C2=C2+C3
  F=GRAPH C1,C2:
  JUMP IF R=100@111
  C1=L6*S24
  C1=C1+C4
  F=GRAPH C1,C2:
  C4=C1
  C3=C2:
  111) REPEAT R
  VARY R=1:1:200
  OUTPUT 0
  REPEAT R
  EXIT
```

124)S1=0::

T5=0

VARY R=0:1:101

YR=0

REPEAT R

READ P4::0 FOR COMMON LOCAL WTS. TAPE: 1, 2, 3, 4 ETC FOR REST.

READ N::NUMBER OF WEIGHTS

VARY I=1:1:N

READ M

READ S

READ B

READ X

B2=S/6

B1=MOD B

JUMP UNLESS B1%B2@63

TITLE

OFFENDING ITEM - B -

PRINT I

LINE

VARY R=0:1:30

OUTPUT 23

REPEAT R::INDICATES BY OUTPUT OF //////////// WHEN ITEM OFFENDS.

WAIT::REMOVE TAPE AND CORRECT

63)Q=X-B

Q1=S/2

Q3=Q+Q1

JUMP UNLESS Q3%L@52

TITLE

OFFENDING ITEM - Q3 -

PRINT I

LINE

VARY R=0:1:30

OUTPUT 23

REPEAT R::INDICATES BY OUTPUT OF //////////// WHEN ITEM OFFENDS.

WAIT::REMOVE TAPE AND CORRECT

52)Q2=Q-Q1

JUMP UNLESS Q2\$0@122

TITLE

OFFENDING ITEM - Q2 -

PRINT I

LINE

VARY R=0:1:30

OUTPUT 23

REPEAT R::INDICATES BY OUTPUT OF //////////// WHEN ITEM OFFENDS.

WAIT

122)S1=S1+M

M1=M\*X

T5=T5+M1

CHECK S1

CHECK T5

Q2=Q2/L6::  
 Q3=Q3/L6  
 J2=INT Q2  
 J3=INT Q3  
 JUMP IF J2=J3@3::  
 F2=FRAC Q2  
 F2=1-F2  
 F2=F2\*L6  
 F3=FRAC Q3  
 F3=F3\*L6  
 JUMP UNLESS B=0@9

ALL SHAPES

A=M/S::  
 JUMP UNLESS J3=J2+1@5  
 JUMP IF F3=0@3::CALCULATION WHEN RECTANGLE LENGTH LESS THAN 2L/100  
 SUBR 46  
 JUMP IF F2=0@4  
 SUBR 36  
 JUMP @22  
 3)A=M/L6  
 4)R=J2  
 YR=YR+A  
 JUMP @22  
 5)JUMP IF F3=0@2  
 SUBR 46  
 2)JUMP IF F2=0@7  
 SUBR 36  
 J2=J2+1  
 7)N1=J3-J2  
 VARY P=0:1:N1  
 R=J2+P  
 YR=YR+A  
 REPEAT P  
 JUMP @22

TRAPEZIUM CALCULATIONS

9)H3=6\*B::  
 H3=H3/S  
 H3=H3+1  
 H3=H3\*M  
 H3=H3/S::FORE ORD.  
 H2=M\*2  
 H2=H2/S  
 H2=H2-H3::REAR ORD.  
 H=H3-H2  
 H=H/S::SLOPE (PER FOOT)  
 JUMP UNLESS J3=J2+1@13  
 JUMP IF F3=0@3



SUBR 64::

JUMP IF F2=0@11

A2=H1+H2

A2=A2/2

SUBR 34

JUMP @22

11) A=H2+H1

A=A/2

R=J2

YR=YR+A

JUMP @22

13) A3=0

JUMP IF F3=0@14

SUBR 64

14) JUMP IF F2=0@18

H1=H\*F2

H1=H2+H1

A2=H1+H2

A2=A2/2

SUBR 34

H2=H1

N1=J3-J2

N1=N1-1

N2=1

SUBR 35

JUMP @22

18) N1=J3-J2

N2=0

SUBR 35

22) REPEAT 1

EXIT

46) A3=A\*F3

A3=A3/L6

R=J3

YR=YR+A3

EXIT

36) A2=A\*F2:  
A2=A2/L6  
R=J2  
YR=YR+A2:  
EXIT

64) H1=H\*F3  
H1=H3-H1  
A3=H1+H3  
A3=A3/2:  
A3=A3\*F3  
A3=A3/L6  
R=J3  
YR=YR+A3  
EXIT

34) A2=A2\*F2:  
A2=A2/L6  
R=J2:  
YR=YR+A2:  
EXIT

35) H=H\*L6  
VARY P=N2:1:N1  
R=J2:  
R=R+P  
H1=H2+H  
A=H1+H2:  
A=A/2:  
H2=H1  
YR=YR+A  
REPEAT P:  
EXIT

30) JUMP UNLESS HJ\$Z(82+J)@47  
UJ=0  
JUMP UNLESS HJ%0@47  
JUMP UNLESS HJ%Z(51+J)@47  
I=0  
37) I=I+1  
JUMP IF HJ%Z(2I)@37  
JUMP IF Z(82+J)%Z(2I)@69  
JUMP IF Z(51+J)%Z(2I-2)@128  
  
UJ=Z(82+J)-Z(2I-2)  
JUMP @70  
128) UJ=Z(82+J)-Z(51+J)  
JUMP @129

69) JUMP IF  $Z(51+J) \% Z(21-2) @ 130$  156 -  
UJ =  $Z(21) - Z(21-2)$   
70) B =  $HJ - Z(21-2)$   
B = B / UJ  
R = I - 1  
UJ =  $O(25J+1) - O(25J+R)$   
UJ = UJ \* B  
UJ =  $O(25J+R) + UJ$   
JUMP @ 47  
130) UJ =  $Z(21) - Z(51+J)$   
129) B =  $HJ - Z(51+J)$   
B = B / UJ  
UJ =  $O(25J+1) * B$   
47) CHECK UJ :: AREA TO WAVE HEIGHT  
EXIT

START 1

LONGITUDINAL STRENGTH OF SHIPS

BENDING MOMENT CALCULATIONS

(Programmed in Elliott Autocode for use on the  
Elliott 803 Digital Computer)

The programme calculates and outputs any or all of the following  
tables and/or graphs:-

- (i) Local Weights distribution.
- (ii) Continuous Weight distribution  
(a) Lloyd's method, (b) Biles Coffin method.
- (iii) Total Weight distribution.
- (iv) Buoyancy.
- (v) Load curve.
- (vi) Shear Force curve.
- (viii) Bending Moment curve.

Ordinate values are given over each of 100 equal divisions of the  
ship's length overall. Values are averaged over every pair progressively  
and are projected forward over the appropriate division in the first five  
of the above tables.

Graph output on the Benson Lehner plotter is provided, if desired.  
Graphs of Shear Force and Bending Moment are continuous polygons, whereas  
the five other graphs consist of a series of straight horizontal lines  
drawn forward from each ordinate in turn.

In the case of Shear Force and Bending Moment, maximum positive and maximum negative values only may be output if required, in order that the data for several loading conditions may be re-run to produce, respectively, all graphs to fixed (preset) scales, dependent on these values.

Output of all of the above tables for one loading condition takes 8 - 10 minutes. Graph output averages about 2 mins. per graph.

Distribution of the Continuous Weight may be performed by either of two methods available : Biles Coffin or Lloyd's (see their RPT. SR 64/15).

31 sections are used overall in the Buoyancy calculations, of which 23 are within and include the perpendiculars, with four aft and four forward.

After the complete set of data has been read in for the first condition, it is only necessary to read in the relevant changes of data for subsequent conditions. The Lightship concentrated items are distributed and permanently stored, as are the calculated Bonjean areas to each even waterline, which follows the initial input of the buoyancy data. Subsequent buoyancy ordinates are determined by calculation from such items as mean draught, and MCT 1", items peculiar to each loading condition.

Programme and Data Tapes - Operating Instructions.

(Programme)

Enter Binary programme tape 4 0 0

0 0 0

Follow with Autocode Plotter Tape 2, entered -4 0 0

0 0 0

(Data)

Enter tape for first condition 4 0 1 6

0 0 0

All subsequent tapes, enter 4 0 1 6

0 0 1 2 6

Notes on Data Tapes

It is advisable to have one complete tape for the first condition, consisting of:-

Scales and Lightship concentrated items (Tape 1)

Deadweight items, displacement, L.C.G.,  
Lloyd's 'a' values (or Biles information) (Tape 2)

Tables/Graphs output constants; Trim data (Tape 3)

Bonjean data (Tape 4)

Tables/Graphs/Max. values output constants (Tape 5)

each tape separated by several inches of blank tape.

Subsequent conditions require to have entered only the changed data of the deadweight items with the appropriate displacement and L.C.G. (Tape 2); Tables/Graphs constants, trim data (Tape 3); and Tables/Graphs/Max. values constants (Tape 5); it is advisable to have these three tapes again as one complete tape. Thus instead of many small tapes, there is one complete tape per condition.

There are programme WAITS after each part of the above compound tapes, for greater control of the data. There is also an immediate WAIT at the beginning, just before the lightship data is fed in, to allow use of an amended tape for a graph re-run. WAIT will also be encountered, apart from those between the 'part tapes' of the subsequent conditions, at the stage when Tape 4 would be expected.

#### Presentation of Data

The following pages show the style and presentations of the data (partially completed), as submitted by the shipyard, and the same data when typed/punched for input to the computer.

- Note: (i) Waterline spacings variable H in the Longitudinal Strength programme replaces variable D in the Bonjean data sheet.
- (ii) Half-widths "YI" in the Bonjean data, are known as "GI" in this programme.

Tape 1. (Required for FIRST data run only).

Sheet (i)

If some (or all) conditions are to be re-run in order to graph all Shear Force curves to the same scale (and similarly the Bending Moment curves), from the maximum values determined on a previous run, PUT 13 = 1.

IN ALL OTHER CASES, PUT 13 = 0.

Programme  
Variable.

0	13
---	----

If 13 = 0, omit this section, and go on to the next section.

If 13 = 1, enter the appropriate maximum values from the previous runs. (If either one is not required, enter two zeros for that curve).

Maximum Shear Force (+ve) tons		S25
" " " (-ve) "		S26
Maximum Bending Moment (+ve) tons/ft.		M6
" " " (-ve) " "		M7

(PROGRAMME WAIT HERE)

0 for Lloyd's method: 1 for Biles Coffin	0	I1
Length Overall ft.	617	L
Length of Stern Overhang "	23	L1
Length of Bow Overhang "	14	L2

Enter 1 for full width graph, 0.5 for half width graph or 0 for no graph	1	S22
Horizontal Scale required (Convenient choice : 10, 20 or 40 - ft/cm.) Enter 0 if no graph required.	20	S27

Code Number for Lightship Concentrated Items	0	P4
Number of Concentrated Lightship Items	71	N



	ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
1.	Lower Bdge Dk & Hse below	75.17	94.50	0	81.75
2.	Upper " " " "	58.96	90.00	0	
3.	Boat " " " "				
4.					
	etc. etc.				
	etc. etc.				
				0	443.50
		45.18	2.25	0	510.12
		20.00	1.00	0	572.00
71.	Capstans	5.48	4.00	0	284.00

\* -ve if aft of Centre of Length.

TAPE 2

Code number for this Sheet - i.e. Condition Number. (1, 2, 3, ... etc.)	1	Pl
Number of DEADWEIGHT Items for this condition	36	H

DEADWEIGHT ITEMS

ITEM	Weight (tons) (M)	Length (ft) (S)	Dist. of L.C.G. * from C/L of Item. (B)	L.C.G. from stern (X)
1. W.B. in No. 1 D.B. Tank	436.00	63.00	-3.87	536.63
2. " " 2 " "	726.00	65.00	-1.34	475.16
3. " " 3 " "	1162.00			
etc. etc.				
etc. etc.				
	100.00	80.00	0	88.00
36. Engineers Spare Gear	40.00	80.00	0	72.45

\* -ve if aft of Centre of Length.

Tape 2 (contd)

Sheet (ii)

TITLE output at Head of Results

= crlf<sup>4</sup>

Name of firm

SHIPYARD A.

Ship No. X

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION No. 1

BALLAST DEPARTURE  
FULL BUNKERS.

\*STILL WATER  
\*~~STNE~~-WAVE SAGGING  
\*~~STNE~~-WAVE HOGGING

(delete those  
\* not  
Required).

Programme  
Variable.

Displacement	(tons)	21318.65	W31
L.C.G. forward of Stern	(ft)	321.79	K3

Tape 2 (Contd). (This part of Tape 2 not required after the first data run).

If Continuous Weight is to be distributed by Biles Coffin method, complete lines (a), (b), (c), (d) below, otherwise complete (e) from Lloyds tables SR 64/15.

Programme  
Variable.

For FIRST data run only:

(a) Weight of Overhang of Stern.	W33
(b) Weight of Overhang of Bow.	W34
(c) L.C.G. of Overhang of Stern, from Stern.	L4
(d) L.C.G. of Overhang of Bow, from Stern.	L5

(e) For FIRST data run only:

	Stn. 0	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6
0	.34	.495	.625	.73	.815	.885	.94
Stn. 7	Stn. 8	Stn. 9	Stn.10	Stn.11	Stn.12	Stn.13	Stn.14
.975	.998	1	1	1	1	1	1
Stn.15	Stn.16	Stn.17	Stn.18	Stn.19	Stn.20		
1	.975	.905	.765	.505	.14	0	

Tape 3

Choice of Output

Control Programme  
Constant Variable

1 if Local Weights Table required : 0 otherwise	1	P1
1 " " " Graph " : 0 otherwise	0	P2
1 " Cont. Weight Table " : 0 otherwise	1	P1
1 " " " " " : 0 otherwise	0	P2
1 " Total " " " : 0 otherwise	1	P1
1 " " " Graph " : 0 otherwise	0	P2

Mean Draught	(ft)	21.245	S17
MCT 1"	ton.ft.	3087	M2
L.C.B. fwd A.E.	(ft)	331.22	L10
L.C.F. fwd A.E.	(ft)	321.63	L11

Wave height (0 if still water)	(ft)	0	S16
Wavelength (0 if still water)	"	0	L19
Enter 1 if Sagging; 0 if hogging or still water		0	P3
Distance (ft) from extreme stern to FIRST crest or trough		0	S18

Tape 4.

There now follows the data from the Hull Definition Sheet:  
(See p.13 and refer to Applications Group Programme LSB 3A)

(i)

D	Q1	N1	N2
3	0.25	7	3

(Bonjean headings  
Data item K is not  
required)

followed by the data for each Section in turn, as under:

(ii)

Section No.	P(J + 5) (1 or 0)	Z <sub>min</sub>	Z <sub>max</sub>

NOTE: Where P(J + 5)  
= ZERO, no further  
values of Z or half-  
widths (y) are entered.  
(LSB 3A does not show  
this variable)

(iii)

Appropriate number of half-widths (vertical columns)

i.e. if Q1 = 0.25 :- 2N + 1 Values where N = (N1 + N2 + 3)

if Q1 = 0.125:- 2N + 1 Values where N = (N1 + N2 + 4)

(iv)

Y <sub>max</sub>	Y <sub>mid</sub>

(NOTE: Y<sub>mid</sub> only when Z<sub>min</sub> ≠ 0)

Tape 5

Choice of Output

	Control Constant	Programme Variable
1 if Buoyancy Table required : 0 otherwise	1	P1
1 " " Graph " : 0 "	0	P2
1 " Load Table " : 0 "	1	P1
1 " " Graph " : 0 "	0	P2
1 " Shear Table " : 0 "	1	P1
1 " " Graph " : 0 "	0	P2
<p>If P2 = 0, but maximum positive and maximum negative values are to be output, PUT 15 = 1:</p> <p>If P2 = 1, and this is a re-run to obtain all graphs to a preset scale, PUT 15 = 1:</p> <p>Otherwise PUT 15 = 0</p>	0	15
1 if Bending Moment Table required : 0 otherwise	1	P1
1 " " Graph " : 0 "	0	P2
<p>If P2 = 0, but maximum positive and maximum negative values are to be output, PUT 16 = 1:</p> <p>If P2 = 1, and this is a re-run to obtain all graphs to a preset scale, PUT 16 = 1:</p> <p>Otherwise PUT 16 = 0</p>	0	16

2. The second part of the report is a detailed account of the work done during the period covered by the report.

3. The third part of the report is a summary of the results of the work done during the period covered by the report.

4. The fourth part of the report is a summary of the conclusions reached during the period covered by the report.

5. The fifth part of the report is a summary of the recommendations made during the period covered by the report.

6. The sixth part of the report is a summary of the work done during the period covered by the report.

7. The seventh part of the report is a summary of the results of the work done during the period covered by the report.

8. The eighth part of the report is a summary of the conclusions reached during the period covered by the report.

9. The ninth part of the report is a summary of the recommendations made during the period covered by the report.

10. The tenth part of the report is a summary of the work done during the period covered by the report.

11. The eleventh part of the report is a summary of the results of the work done during the period covered by the report.

12. The twelfth part of the report is a summary of the conclusions reached during the period covered by the report.

13. The thirteenth part of the report is a summary of the recommendations made during the period covered by the report.

14. The fourteenth part of the report is a summary of the work done during the period covered by the report.

15. The fifteenth part of the report is a summary of the results of the work done during the period covered by the report.

16. The sixteenth part of the report is a summary of the conclusions reached during the period covered by the report.

17. The seventeenth part of the report is a summary of the recommendations made during the period covered by the report.

18. The eighteenth part of the report is a summary of the work done during the period covered by the report.

19. The nineteenth part of the report is a summary of the results of the work done during the period covered by the report.





The overall pattern of the data is as follows:-

1st Condition.

(Enter 40 16  
00 0)

Tape 1. 13, (with S25, S26, M6, M7 only if I3 = 1).

WAIT

I1, L, L1, L2, S22, S27.

P4 (=0), N followed by M, S, B, X ..... (N times).

WAIT

Tape 2.

P4 (=1), N followed by M, S, B, X ..... (N times).

TITLE

W31, K3 followed by 23 "a" values (Lloyd's method) OR  
W33, W34, L4, L5 (Biles Coffin method).

WAIT

Tape 3.

P1, P2, P1, P2, P1, P2. (1s or 0s)\*\*

(If tape misreads after  
\*\* it may be re-entered  
on 40 16  
00 90 )

SL7, M2, L10, L11, SL6, L9, P3, SL8.

WAIT

Tape 4.

(In case of misread, re-enter 40 16  
00 123)

H, Q1, N1, N2 followed, for each Section in turn, by:

SL9, P(J+5), Z(51+J), Z(82+J)

(Note:  
If, for any section,  
P(J+5) = 0, no more  
values are entered for  
this section after R(J+5))

Appropriate number of half widths (GI)

G52, (with G51 if Z(51+J) ≠ 0)

WAIT

Tape 5.

P1, P2, P1, P2, P1, P2, I5, P1, P2, I6.

2nd (and subsequent) Conditions.

Tape 1. Not required.

Tape 2. (Enter 40 0  
00 126)

P4 (=2, 3, 4 etc., depending on Condition), N followed by:-

TITLE

M, S, B, X ..... (N times).

WAIT

Tape 3.

P1, P2, P1, P2, P1, P2. (1s or 0s) \*\*

(If tape misreads after  
\*\* it may be re-entered  
on 40 16  
00 90 )

SL7, M2, L10, L11, SL6, L9, P3, SL8.

WAIT

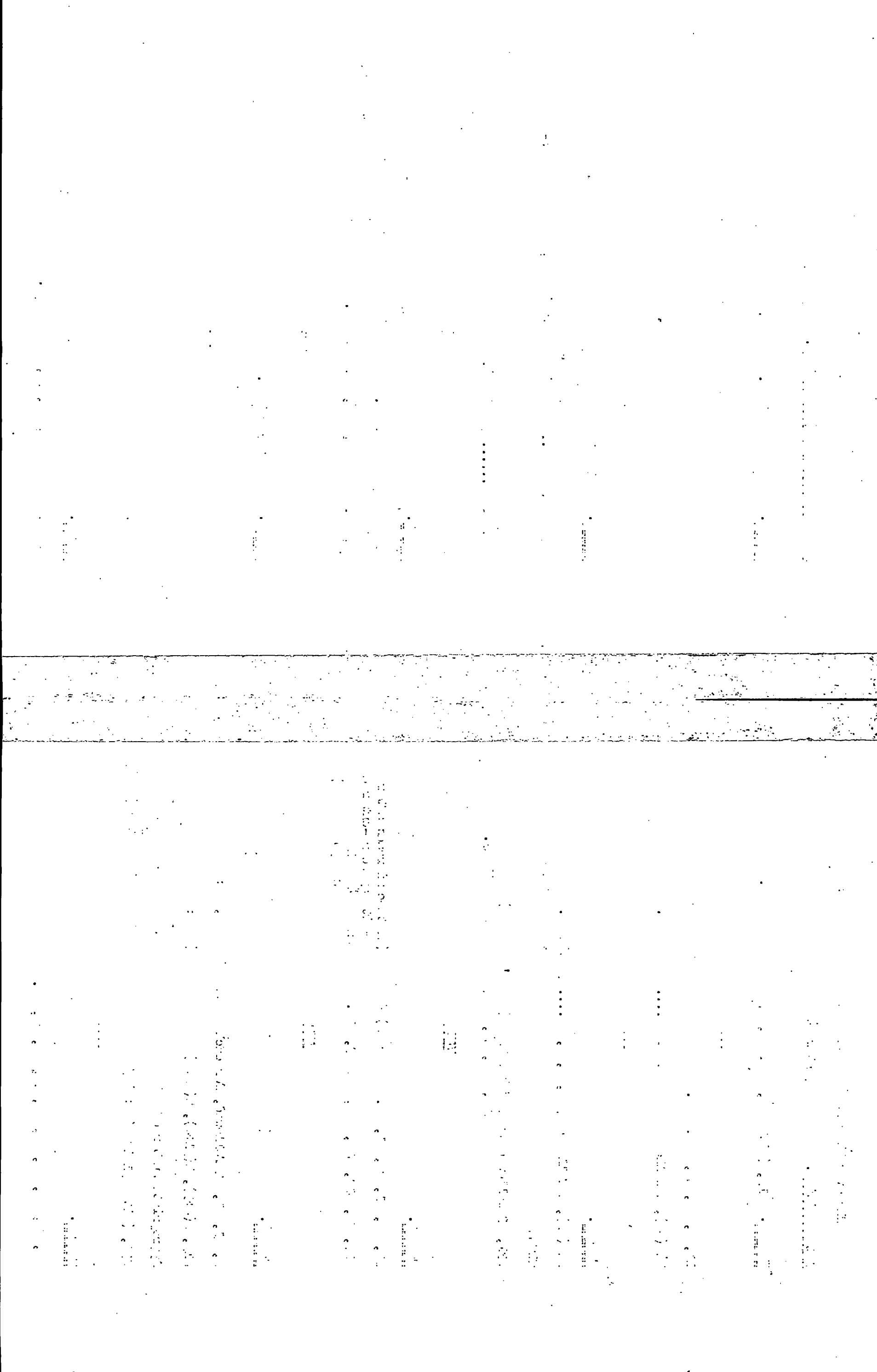
Tape 4.

Not required.

WAIT

Tape 5.

P1, P2, P1, P2, P1, P2, I5, P1, P2, I6.



(Tape 1)

Condition 1.

0

I3 (No max. values if zero)

0 617 23 14 0.5 20

I1, L, L1, L2, S22, S27.

0 71

P4, N.

M, S, B, X.....(N times)

75.17	94.5	0	81.75
58.96	90	0	83
47.09	78.5	0	88.25
15.65	32.75	0	110.38
12.5	25	0	116.5
26.21	36	0	536.25
26.3	36.5	0	487.5
12.76	17.5	0	432.75
27.35	37.5	0	380.25
27.35	37.5	0	317.75
12.76	17.5	0	265.25
27.35	37.5	0	220.25
27.35	37.5	0	157.75
2.42	6	0	559.25
4.65	17.5	0	451.0
5.87	25	0	349
4.65	17.5	0	247.75
2.42	6	0	136
28.3	15.75	0	508.13
27.9	15	0	411.5
27.9	15	0	286.5
27.9	15	0	189
15.5	2.5	0	508.13
15.5	2.5	0	411.5
15.5	2.5	0	286.5
15.5	2.5	0	189
12	9	0	577.75
11.63	6	0	592.5
59.95	8	0	576
6.1	51	-8.5	580
16	34.5	+5.75	23
19.61	28	+1	84.5
7.5	26	0	87.5
22.4	19	+2	33
16.3	6	0	30.5
10.2	12.25	0	20.38
6.5	7.25	0	23

(Tape 1 Cont.)

3.1 91 0 83.75  
 30 91 0 83.75  
 3.5 6 0 48  
 13 19.5 +1.75 46  
 10 91 0 83.75  
 12 91 0 83.75  
 35 580 0 313  
 85.75 580 0 313  
 20 580 0 313  
 45 448 0 348  
 376 28.5 -1.33 95.42  
 42.6 16.33 0 61.5  
 258.47 80 +12.43 96.43  
 26.43 40 0 54  
 6 10 0 39  
 42.36 80 0 84  
 40.8 80 0 84  
 69.18 98.5 16.416 113.25  
 34 51 -8.5 580  
 1.5 4 0.6666 110.5  
 15.45 18.25 0 60  
 11.5 16.75 0 59  
 5.81 8 1.3333 416.5  
 8 1 0 44  
 27.13 1.08 0 124.54  
 45.77 2.17 0 187.92  
 77.84 1 0 254.5  
 77.84 1 0 283.5  
 47.49 2.17 0 350.08  
 77.84 1 0 414.5  
 77.84 1 0 443.5  
 45.18 2.25 0 510.12  
 20 1 0 572  
 5.48 4 0 284

End of Tape 1.

- - - - -

(Tape 2).

1 36

P4, N.

436	63	-3.87	536.63
726	65	-1.34	475.16
1162	95	+0.13	396.63
668	95	+1.12	302.62
486	95	-0.01	301.49
824	112.25	-5	495.12
700	95	0	396.5
700	95	0	301.5
478	65	0	221.5
454	31.7	-5.283	582.42
290	20	+2.16	35.16
2738	30	-0.08	429.08
2738	30	-0.08	268.92
233.24	65	0	221.5
348.88	65	+2.62	224.12
194.04	67.5	+3.6	158.85
133.28	67.5	+5.47	160.72
415.52	65	+0.31	156.81
20.58	6.25	0	89.63
20.58	6.25	0	95.88
41.16	12.5	0	105.25
60.27	67.5	-0.37	154.88
23.28	32.5	+3.42	103.67
14.45	15	+0.6	109.6
12	3.75	0	113.38
11.52	3.75	0	117.13
12.25	27.5	0	85.25
5.88	3.33	0	65.67
6.13	3.33	0	69
6.13	3.33	0	72.33
13.96	7.5	0	77.75
12.25	5	0	81.5
29.25	22.5	+1.55	59.3
55	14	0	37
100	80	0	88
40	80	0	72.45

M, S, B, X....(N times)  
(i.e. 36 times)

(Tape 2 Cont.)

SHIPYARD A.

SHIP NO. X

LONGITUDINAL STRENGTH CALCULATIONS

CONDITION 1, BALLAST DEPARTURE  
FULL BUNKERS.

STILL WATER.

21318.65

321.79

W31, K3.

0	.34	.495	.625	.73	.815	.885	.94	.975	.998	1	1	1
1	1	1	.975	.905	.765	.505	.14	0				

(23 Lloyd's "a" values)

End of Tape 2.

- - - - -

(Tape 3)

1 0 1 0 1 0

P1, P2, P1, P2, P1, P2.

21.245 3087 331.22 321.63 0 0 0 0

S17, M2, L10, L11, S16, L9,  
P3, S18.

End of Tape 3.

- - - - -

(Tape 4)

3 .25 7 3

H, Q1, N1, N2.

0 0

S19, P(J+5), No further rdgs.  
if P(J+5) = 0  
Z(51+J), Z(82+J)

1 1 34.313 49.407  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 2.25 5.167  
7.583 9.75 11.646 0 0 0 0 0 0 (1+2(N1+N2+3)) half  
12.447 1.396 G52, G51. widths

2 1 29 49.290  
0 0 0 0 0 0 0 0 0 0 0 0 1.573 4.88 7.969  
10.677 13.031 15.063 16.813 0 0 0 0 0 0  
17.465 1.037

3 1 26.292 49.181  
0 0 0 0 0 0 0 0 0 0 0 1.38 5.162 8.755  
11.901 14.583 16.932 18.906 20.589 0 0 0 0 0 0  
21.184 2.917

4 1 24.304 48.985  
0 0 0 0 0 0 0 0 0 0 4.229 8.234 11.969  
15.130 17.802 20.094 22.042 23.703 0 0 0 0 0 0  
24.196 4.55

5 1 21.865 48.740  
0 0 0 0 0 0 0 0 0 3.365 7.667 11.693  
15.412 18.568 21.214 23.458 25.37 27.042 0 0 0 0 0  
27.395 1.750

6 1 0 48.598  
1.042 1.083 1.109 1.12 1.13 1.146 1.162 1.182 1.208  
1.245 1.557 3.162 6.802 10.885 14.839 18.427 21.479  
24.078 26.271 28.12 29.745 0 0 0 0 0 0  
30.021

7 1 0 48.48  
1.047 1.51 1.813 2 2.151 2.385 2.583 2.917 3.281  
3.807 4.818 6.802 10.109 13.932 17.702 21.109 24  
26.505 28.625 30.391 31.912 0 0 0 0 0 0  
32.124



(Tape 4 Cont.)

8 1 0 48.394  
 1.406 2.063 2.537 2.880 3.172 3.625 4.005 4.651 5.354  
 6.37 7.901 10.219 13.313 16.880 20.401 23.521 26.292  
 28.646 30.641 32.281 33.656 0 0 0 0 0 0  
 33.818

9 1 0 48.25  
 2.12 3.469 4.219 4.813 5.307 6.162 6.88 8.224 9.687  
 11.453 13.687 16.323 19.224 22.307 25.234 27.885 30.245  
 32.255 33.932 35.255 36.313 0 0 0 0 0 0  
 36.391

10 1 0 48.154  
 3.13 5.266 6.245 7.037 7.724 8.875 9.922 11.964 14.073  
 16.354 18.849 21.583 24.323 26.984 29.422 31.599 33.5  
 35.083 36.344 37.333 38.115 0 0 0 0 0 0  
 38.142

11 1 0 48.04  
 6.406 9.724 11.182 12.313 13.307 15.099 16.698 19.615  
 22.339 24.974 27.531 29.948 32.099 34 35.630 36.99  
 38.104 38.927 39.526 39.969 40.276 0 0 0 0 0 0  
 40.273

12 1 0 48.00  
 11.078 15.0 16.854 18.302 19.542 21.662 23.448 26.542  
 29.182 31.488 33.531 35.328 36.818 38.068 39.068 39.828  
 40.354 40.693 40.875 40.974 41.00 0 0 0 0 0 0  
 41

13 1 0 48.00  
 21.552 26.24 28.281 29.807 31.037 32.969 34.479 36.693  
 38.198 39.24 39.964 40.448 40.766 40.938 41 41 41 41  
 41 41 41 0 0 0 0 0 0  
 41

14 1 0 48  
 30.813 34.547 36.12 37.24 38.109 39.349 40.146 40.88 4  
 41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 00  
 41

(Tape 4 Cont.)

15 1 0 48  
34.5 37.537 38.656 39.427 39.979 40.688 40.979 41 41  
41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 0  
0  
41

16 1 0 48  
34.5 37.537 38.656 39.427 39.979 40.688 40.979 41 41  
41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 0  
0  
41

17 1 0 48  
34.5 37.537 38.656 39.427 39.979 40.688 40.979 41 41  
41 41 41 41 41 41 41 41 41 41 41 0 0 0 0 0  
41  
41

18 1 0 49.666  
28.76 32.776 34.307 35.370 36.188 37.401 38.24 39.276  
39.781 40.042 40.188 40.281 40.339 40.396 40.448 40.5  
40.552 40.604 40.656 40.714 40.760 40.787 0 0 0 0 0  
40.787

19 1 0 51.175  
20.807 25.359 27.271 28.609 29.667 31.26 32.448 34.109  
35.193 35.901 36.412 36.792 37.104 37.359 37.573 37.76  
37.932 38.12 38.292 38.464 38.63 38.719 38.802 0 0 00  
38.815

20 1 0 52.865  
11.469 15.958 17.74 19.078 20.188 21.901 23.25 25.177  
26.458 27.396 28.151 28.74 29.24 29.688 30.12 30.51  
30.896 31.302 31.719 32.135 32.583 32.813 33.063 33.307  
33.31 0 0  
33.37

21 1 0 53.809  
6.927 10.828 12.488 13.719 14.729 16.318 17.531 19.313  
20.516 21.422 22.115 22.698 23.208 23.672 24.125 24.578  
25.073 25.563 26.146 26.771 27.427 27.771 28.141 28.516  
0 0 0  
28.851

22 1 0 54.828  
2.74 5.656 7.031 8.052 8.88 10.208 11.219 12.687 13.67  
14.443 15.047 15.552 16 16.438 16.87 17.344 17.87 18.3  
19.104 19.849 20.672 21.109 21.568 22.047 22.583 0 0  
22.875

23 1 0 55.197  
.964 3.063 4.25 5.135 5.849 6.995 7.885 9.156 10.042  
10.698 11.193 11.635 12.047 12.464 12.885 13.359 13.885  
14.474 15.125 15.875 16.729 17.188 17.677 18.203 18.740  
0 0  
19.198

24 1 .135 55.55  
0 .698 1.505 2.162 2.734 3.708 4.448 5.542 6.297 6.83  
7.240 7.620 7.979 8.354 8.740 9.162 9.651 10.188 10.83  
11.583 12.427 12.875 13.375 13.891 14.458 15.063 0  
15.093 .823

25 1 3.958 55.9  
0 0 0 0 0 .302 .896 1.813 2.453 2.865 3.188 3.479  
3.776 4.083 4.427 4.792 5.193 5.687 6.281 6.979 7.792  
8.240 8.729 9.25 9.849 10.469 0  
10.648 .521

26 1 33 56.25  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.63 1.063  
1.573 2.182 2.917 3.349 3.807 4.323 4.875 5.479 0  
5.766 0.427

27 1 42 56.334  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
1.01 1.714 2.12 2.573 3.063 3.615 4.208 0  
4.519 1.01

28 1 48.281 56.421  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
0 0 0 1.323 1.781 2.333 2.901 0  
3.326 .906

29 1 53.188 56.507  
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 .932 1.583 0  
2.132 .667

30 0

End of Tape 4.  
-- -- -- --

(Tape 5)

1 0 1 0 1 0 0 1 0 0 P1, P2, P1, P2,  
P1, P2, I5, P1, P2, I6.  
194.04 667.5 +3.6 158.85  
133.28 67.5 +5.47 160.72  
415.52 65 +0.31 156.81  
20.58 6.25 0 89.63  
20.58 6.25 0 95.88  
41.16 12.5 0 105.25  
60.27 67.5 -0.37 154.88  
23.28 32.5 +3.42 103.67  
14.45 15 +0.6 109.6  
12 3.75 0 113.38  
11.52 3.75 0 117.13  
12.25 27.5 0 85.25  
5.88 3.33 0 65.67  
6.13 3.33 0 69  
6.13 3.33 0 72.33  
13.96 7.5 0 77.75  
12.25 5 0 81.5  
29.25 22.5 +1.55 59.3  
55 14 0 37  
100 80 0 88  
40 80 0 72.5

(Tape 5)

1 0 1 0 1 0 0 1 0 0

End of Tape 5 and Condition 3.  
-- -- -- --

1. The first step is to identify the problem or question that needs to be addressed. This involves understanding the context and the specific requirements of the task.

(.0000000000)

.E. Robinson  
 1000 1st St. (BT)  
 Berkeley Ca.

2000

72 5

[illegible]

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(Tape 2 Cont.)

=

SHIPYARD A.

SHIP NO. X

LONGITUDINAL STRENGTH CALCULATIONS  
STILL WATER

CONDITION 5, LOADED DEPARTURE  
HEAVY CARGO IN NOS. 1, 4, 5 AND 8 HOLDS.

FULL BUNKERS

34958.65  
317.43

End of Tape 2.

- - - - -

(Tape 3).

0 0 0 0 0 0

33.083 3839 324.52 306.72 0 0 0 0

End of Tape 3.

- - - - -

(Tape 5).

0 0 0 0 0 0 1 0 0 1

End of Tape 5 and Condition 5.

- - - - -

Note concerning Shear Force and Bending Moment curves.

The programme will normally choose the scale to give the largest graph possible. This means that each Shear Force graph (for a set of conditions) will have its own scale. Similarly with the Bending Moment graphs.

It has been found convenient in the case of these two graphs to fix the scale, from previously output maximum positive and maximum negative shear force values.

To obtain these maximum values only, for each condition run, put I3 = 0, and I5 (for Shear Force) and I6 (for Bending Moment) both equal to 1, while P2 (for graph output) = 0 (no graph). This does not affect output of any of the tables (P1 = 1 for tables, 0 for no table), or any of the graphs preceding Shear Force (for which P2 = 1 for graphs, or 0 for no graph). The overall maximum values are noted.

On the re-run it is necessary to alter Tape 1; I3 is now made = 1, and the four maximum values follow this. (If ONLY Shear Force OR Bending Moment is wanted, the other two values must be put = 0). There is a programme WAIT here to allow the remainder of the original Tape 1 to be entered. It is now necessary to alter Tape 5, so that P2 for the required graphs = 1, with I5 = 1 for the Shear Force graph, and I6 = 1 for the Bending Moment graph. Subsequent conditions are entered as before, i.e. 40 16: 00 126. The new altered Tape 5 may be used as a common tape now for all conditions.

Only the output for Condition 1 will have the scales, etc., indicated in the print-up to the graph tape. All other conditions will merely have the words "Shear Force Curve" (or "Bending Moment Curve"), prior to the graph tape, as a record for future reference that the graph has been output to a preset scale.





LONGITUDINAL STRENGTH.

SHIP No. 827.

CONDITION — BALLAST ARRIVAL (DEEP TANK FULL).

SCALES: —

HORIZONTAL: —  $\frac{1}{16}'' = 1 \text{ FOOT}$

VERTICAL: —

WEIGHT, LOAD & BUOYANCY CURVES  $\frac{1}{16}'' = 1 \text{ TON/FOOT}$

SHEAR FORCE  $\frac{1}{8}'' = 1 \text{ TON}$

BENDING MOMENT  $\frac{1}{4}'' = 10,000 \text{ TON-FT}$

SUPERIMPOSED COMPUTER VALUES

FOR WEIGHT CURVE.

BUOYANCY CURVE.

BENDING MOMENT CURVE.

WEIGHT

BUOYANCY

BENDING MOMENT

